METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR AUGUST, 1954 Vol. 50 No. 298

PUBLISHED MONTHLY BY

The Kennedy Press, Ltd.,
31, King Street West,
Manchester, 3.
Telephone: BLAckfriars 2084

London Office:
50, Temple Chambers,
Temple Avenue, E.C.4.
CENtral 8914

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Readers are invited to submit articles for publication in the editorial pages: photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

SUBSCRIPTIONS

Subscription Rates throughout the World—24/- per annum, Post free.

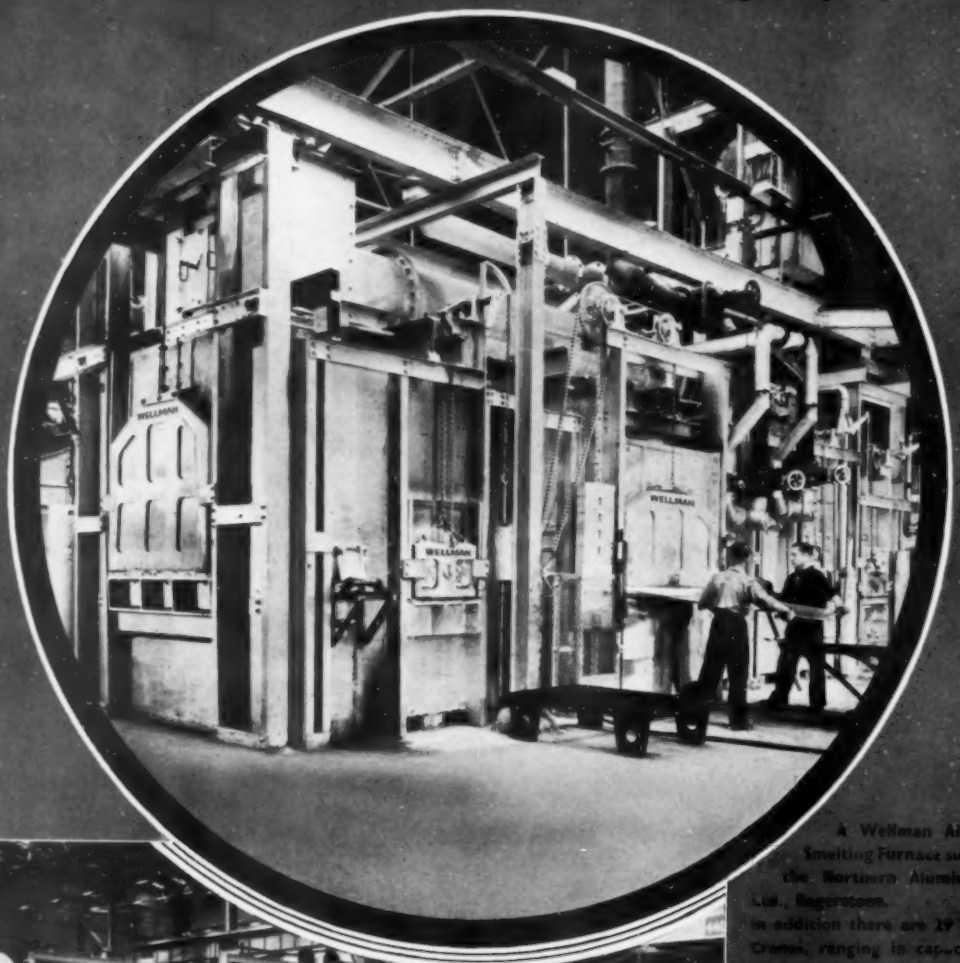
ADVERTISING

Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

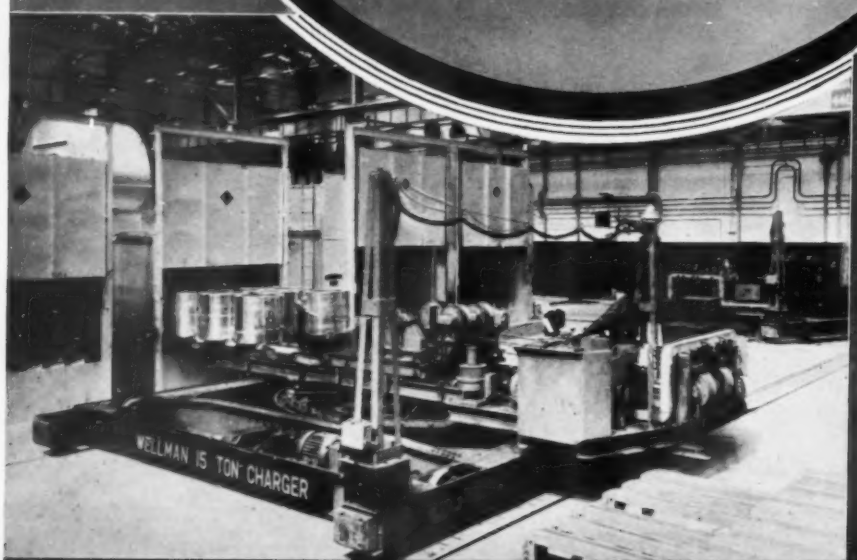
The articles in this Journal are indexed in THE INDUSTRIAL ARTS INDEX

WELLMAN

Furnaces and Mechanical Handling Equipment



A Wellman Aluminium Smelting Furnace supplied to the Northern Aluminium Co. Ltd., Rogerstown.
In addition there are 19 Wellman Cranes, ranging in capacity from 5 tons to 40 tons, in operation at these Works.



Wellman 15 ton Finger Type Charger's and Turntable in service at the British Aluminium Co. Ltd., Falkirk. This installation also includes a 10,000 lbs. Wellman Slab Discharger and a 10,000 lbs. Block Handling Crane.

THE WELLMAN SMITH OWEN ENGINEERING CORPN. LTD.
PARNELL HOUSE, WILTON ROAD, LONDON, S.W.1 WORKS: DARLASTON, SOUTH STAFFS.

METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

August, 1954 Vol. L. No. 298

Longer Academic Training?

"IT is impossible at present to imagine the future of our country except in relation to our engineering industries, industries which dominate our economy and the foreign trade upon which our ability to feed ourselves is dependent," said The Rt. Hon. The Earl of Halsbury, F.R.I.C., F. Inst. P., Managing Director of the National Research Corporation, in introducing his Sir Alfred Herbert paper to the Institution of Production Engineers at the Production Conference at Olympia last month. Lord Halsbury continued by pointing out that these industries depend on many factors, each of which is like a gear wheel in a complex transmission system. In this sense, operatives — unskilled, semi-skilled and skilled — accountants, salesmen, administrators and executives are all essential, as is every wheel in a gear box, but the prime mover that turns the wheels is, and can only be, the creative professional engineer.

Because of this, Lord Halsbury felt that to choose as the subject of his paper a study of the provisions made for the training of engineers required little justification on his part. In reviewing the influence of the universities, the professional institutions and industry on the educational trend, he made a number of observations which, although primarily related to engineering, are of little, if any, less interest to other branches of technology. Without in any way attempting to survey the whole of the paper, it may be worth while to consider some of the points raised.

According to the biologists, one of the main differences between man and the other animals lies in his prolonged immaturity, which results in his nature being plastic and changeable to an extent not found elsewhere in the biological world, and this plasticity is directly dependent on delayed specialisation and a prolonged immaturity. It follows, therefore, that a certain immaturity is a natural accompaniment of a prolonged education, and that if a man's purely intellectual development is prolonged from school, through a degree course, and then through a period of post-graduate training, he is likely, at first, to be somewhat underdeveloped in such qualities as resourcefulness, decisiveness, practicability and common sense. If this is the case, then it is obvious that such a man entering industry does so with something of a handicap, and it is essential that he should be handled sympathetically, so as to encourage him to remedy his shortcomings as quickly as possible. At the age of twenty-five or -six, he is still capable of being moulded on the right lines, even if he is a little less plastic than at twenty-one. What is more, given suitable guidance, he will, subsequently, more than repay the forbearance shown to him in his early days in industry. The foregoing should not be taken as a criticism of the universities. With the advancing frontiers of science they have their work cut out to see that the student receives an adequate technical training, quite apart from the introduction of a sprinkling of the humanities into his curriculum. Moreover, the very atmosphere which is conducive to study and the development of the mind results in at least a partial sheltering from the hurly-burly of everyday industrial life.

In spite of the difficulties referred to, Lord Halsbury felt there was a need in industry for men with a longer academic training, and suggested that we ought to think of university titles as dependent on whether academic training had lasted three, five or seven years, on the grounds that two men differing by only one year's training remain the same type, whereas with a differential of two years a real difference begins to emerge, and to colour their subsequent careers*. The degrees corresponding to these periods of training would be Bachelor, Master and Doctor, and all grades would be required by industry. In the engineering sciences the Bachelor would be suitable for careers concerned with maintenance, line production, and design in the field of standard practice; the Master for specialist teams, research work, and design in the field of essential novelty and production; and the Doctors would provide the thinkers and the theorists.

Besides the problem of the relative under-development of the qualities of character and personality referred to earlier, a prolonged education, particularly if one considers the seven-year course, also brings in its trail economic problems related to the deferment of earning power in the expectation of a return later. Whether or not young men will be willing to accept this deferment will be very largely governed by the subsequent reward, and until employers are sufficiently convinced of the value of post-graduate training to make it worth while to the student, industry will continue to be starved of some of those trained technologists it cannot afford to be without. One American oil firm quoted by Lord Halsbury put its policy as follows. "We reckon we need all sorts of engineering standards in our organisation, pass men, honours men, M.Sc.'s and Ph.D.'s; and we reckon it's up to us to stimulate the supply. So we offer $1,000 differential on starting salaries between each grade: that means $4,000 to a pass man rising to $7,000 for a Ph.D. Other U.S. statistics indicate that of two groups of engineers, one having had five years at a university, and the other having had three years at a university and two in industry, the former group is at an economic advantage of 1·7 to 1 over the latter in their sixth years. In other words, the belief that a man with a longer academic training is wanted in the engineering industry is confirmed in the United States by the most acid test of all, the employers' willingness to stimulate the training of that type of recruit by a willingness to provide an attractive starting differential.

These are points on which there is obviously room for more than one opinion, and no doubt many employers remain to be convinced that prolonged academic training is necessary for recruits to industry.

* The post-graduate training in this scheme does not necessarily involve research in the generally accepted sense of the term.

New and Revised British Standards

METHODS OF SAMPLING AND TESTING BOILER WATER DEPOSITS (B.S.2455 : 1954) Price 6s.

FOLLOWING on various standards issued by the British Standards Institution, for water used in steam generation, a further document has now been published, namely B.S.2455, "Methods of Sampling and Testing Boiler Water Deposits." B.S.1328, "Methods of Sampling Water used in Steam Generation" and B.S.1427, "Tests for Water used in Steam Generation: Group A" were drawn up to provide, not only a series of standard methods for the sampling and examination of waters, but also for the reporting and recording of the results obtained in the tests. The object was to make possible a direct comparison between the findings of different workers.

B.S. 2455, which is complementary to those mentioned, has the same object, but it applies not to the waters used but to deposits forming in various parts of the equipment concerned with the generation. The standard is divided into sections in which terms used are explained and methods are recommended for collecting and describing samples, for their chemical and physical examination and for reporting the results obtained.

B.S.2455 is confined to a description of methods suitable for the more general problems encountered, but does not cater for special cases, except insofar as reference is made to the possibility of physical methods of analysis. It is appreciated, however, that in such special cases elements other than those determined in this standard may be of interest, e.g. zinc, nickel, chromium, and that the ionic form of the copper and the iron may at times be of interest. It is also known that the quantity of sample recommended for analysis will not always be available, particularly in the case of small deposits of corrosion products in high pressure boilers, and that in such cases semi-micro or even micro techniques may be needed.

The methods of chemical examination have been selected so as to require the minimum of time consistent with yielding results of an accuracy adequate for the purposes required. The following determinations are included—oil, loss on ignition, phosphate, carbonate, sulphate, chloride, sodium, silica, copper, iron, aluminium, calcium, magnesium and water soluble salts.

THE TREATMENT OF WATER FOR LAND BOILERS (B.S.2486 : 1954) Price 6s.

THIS standard is a complementary volume to B.S.1170 "Treatment of Water for Marine Boilers" which has proved to be valuable and has been in widespread daily use since its publication in 1947. The production of the present code for land boilers has proved to be considerably more complex, due to the greater variety of boilers in use in land installations. It is particularly directed to the needs of operators of steam generating plant as used widely in industry and usually operated at a pressure not exceeding 250 lb./sq. in.

There are two sides to a boiler, the fire side and the water side. In the majority of boiler installations much time and care are expended on keeping the fire side free from accumulation of deposit that would tend to interfere with adequate heat transference. However, it is unfortunately true, in spite of the simplicity and certainty of many forms of modern water treatment, that in many of the lower pressure boilers little or no attempt is made to keep the water side free from deposits. Scale on the water side can be far more dangerous than deposits on the fire side, since although the latter prevents the heat from reaching the metal the former prevents the heat from being transferred from the metal to the water. This may result in overheating of the metal and consequent failure and risk of explosion.

The desirable feed to all boilers is suitably conditioned water, as free as possible from all unwanted salts and gases, but such water is frequently not provided in the case of the average low-pressure land boiler, and the feed consists of whatever water is available. Such water may contain objectionable impurities, but in general there is no excuse for putting these impurities into the boiler in a harmful form. There are many relatively simple methods of water treatment, the use of which will ensure freedom from scale as well as protection of the boiler from corrosion. Care should be exercised, therefore, in making use of B.S. 2486, the advice of a technical specialist being usually desirable before deciding to adopt any particular form of water treatment. This is especially important with boilers operating at pressures above 200 lb./sq.in.

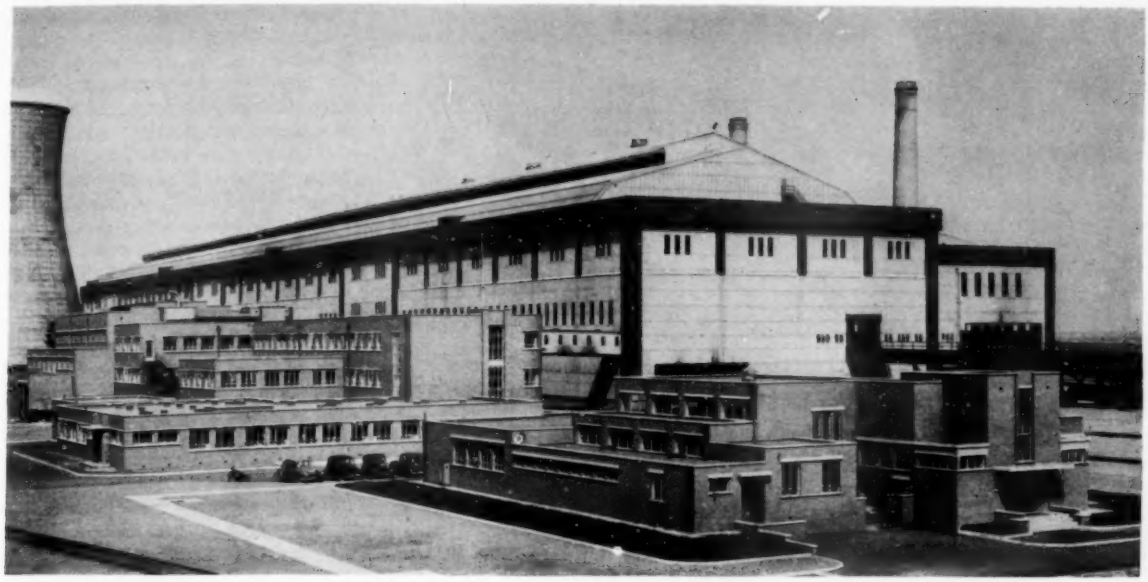
The purpose of this standard is to show how impurities in the water affect boiler plant and to assist in the application of an economical method of treatment suitable to the individual supply. The document is divided into parts dealing with water supplies and their treatment, feed water and boiler water and the care of boiler installations. Additionally, a glossary of terms used in water treatment is included as an appendix.

Copies of these standards may be obtained from the British Standards Institution, British Standards House, 2, Park Street, London, W.1.

Post-Graduate Physical Metallurgy

THE work of the Post-Graduate School of Physical Metallurgy in the University of Sheffield during the session 1954–1955 will be divided into six courses, each complete in itself. In most cases, by separating the lecture course from the associated advanced practical work, it is now possible to offer courses of one or two weeks duration in the hope that more metallurgists from industry will be able to attend. Wherever possible, students are recommended to attend both the lecture and practical sessions of the course, as experience has shown that much greater benefit then accrues. The branches of study covered include metallurgical techniques; deformation of metals (with special reference to creep and fatigue); physical metallurgy of heat-treatment; alloy theory of steels; internal stresses; and annealing of cold-worked metals. A one week course in electron microscopy and two-week courses in X-ray crystallographic methods and optical techniques can also be offered.

The fee for the session is £50, and for a five-week course £21, two-week course £15, and one-week course £10. Further particulars and application forms may be obtained from the Registrar, The University, Western Bank, Sheffield, 10.



New Dorman Long Steelworks

First Plant in Operation on Lacken by Site

The acquisition in 1946 of land joining their Cleveland and Redcar Works has enabled Dorman Long & Co., Ltd., to prepare a development plan involving considerable integration of production between these two works and a new works to be built on the new site. The Lackenby steel plant, part of the second stage of the plan, is now in operation.

THE growth of the Cleveland iron and steel industry presents features common to most other industrial areas. It was founded in a district close to its principal raw materials, in this instance Cleveland ironstone and Durham coal ; from relatively small beginnings it has advanced through subsequent amalgamations into larger groups ; and it is dependent to an increasing extent on imports of foreign ores. The Cleveland industry has, however, one advantage, which is of growing importance as the resources of local ironstone diminish ; situated close to the River Tees, it has easy access by sea for the import of ore from foreign sources.

Of the four steelworks at present in the Dorman Long group, two, Britannia and Acklam, lie adjacent to one another, on restricted sites in Middlesbrough. The other two, Cleveland and Redcar, lie to the east of the town, and are separated by a strip of agricultural land, about two and a half miles long and half a mile wide, bounded on one side by the railway connecting Middlesbrough and Redcar, and on the other by the trunk road between these towns. Until recently, therefore, no direct communication for the exchange of raw and semi-finished materials, electric power or fuel gas was possible between any of the four works except Acklam and Britannia.

In 1946, the whole of the land between the Cleveland and Redcar Works, an area of 680 acres, known as the Lackenby site, was purchased by the Company. The acquisition of this land provided a site large enough not only for a complete new steel furnace and rolling mill plant, laid out on the most modern lines, but also sufficient land for any further development likely for many years. The site also made possible the direct exchange of molten blast furnace metal, hot ingots, fuel gas and electric power between the Cleveland and Redcar Works, with all the economic advantages accruing from this interchangeability.

The first stage in this integration of production, completed in 1949, included the provision of modern ore unloading equipment and ore preparation and sinter plant at the Cleveland Works. Stage II, finished at the end of last year comprised the doubling of the ore preparation and sintering plant, and the putting into operation of a new open hearth steel melting plant as the first unit on the Lackenby site. The third stage provides for the installation at Cleveland of a coke oven plant, two new blast furnaces, a new blooming mill, a new medium section mill, and a new high-capacity rod and bar mill, whilst a combined universal beam and heavy section mill is to be built alongside the melting shop at Lackenby. The new coke oven plant will comprise 150 combination under-jet ovens, constructed in 10 batches of 15 ovens each to facilitate re-building. It is designed to produce 15,000 tons/week of graded coke, and 2,000 tons/week of coke smalls.

Layout of the New Works

The Lackenby site is rectangular in shape, with its longer axis lying roughly north-east to south-west, and the new steelplant, which has been built to replace the

Britannia melting shop, lies diagonally across it, with its main axis practically north to south. This arrangement not only makes available additional length for the steel plant, and for future rolling mills, but also permits a good layout of the railway curves between the exchange sidings, lying parallel to the British Railway line, and the works running roads, most of which lie parallel to the main axis of the steel plant.

The plant is designed to produce 625,000 tons of steel ingots a year from five open hearth furnaces of 360 tons capacity, and two mixers, each holding 600 tons. There is, however, sufficient space to allow this one melting shop to be extended to give an annual output of 900,000 tons. The 360 ton tilting furnaces are larger than any built hitherto in this country, and the whole plant is expected to give the required output even under adverse conditions of a high metallurgical load and a shortage of scrap. To date, the average weekly production from four-furnace operation is 12,534 tons, with a top figure of 13,292 tons, and best weekly make for an individual furnace of 4,047 tons.

The method of charging adopted demands a long inclined ramp for railway wagons, leading to an elevated stock bay lying immediately behind, and the full length of, the furnace charging stage. In order to keep all incoming materials flowing approximately in one direction, this ramp has been placed at the south end of the main shop, remote from the exchange sidings, and the works sorting and standage sidings have been placed on the direct route from one to the other.

From the south end of the sorting sidings, scrap, ore and scale are drawn into a shunting neck at the extreme south end of the plant and pushed up the ramp to the stock bay stage. Along one side is the bench holding the furnace charging boxes, which are refilled by overhead magnet cranes as they are emptied into the furnace by the overhead revolving charging machines in the adjacent bay. The level of the rail tracks in the stock bay brings the top of the average wagon level with the top of a charging box standing on the bench. Molten metal from the blast furnaces at the Cleveland or Redcar Works is brought in 70-ton ladles into the casting bay, where it is picked up by the crane for pouring into the mixers. The remaining furnace charge and repair materials are drawn from their own sorting sidings for storage or preparation in the furnace materials plant.

Outgoing materials from the steel plant consist almost entirely of ingots and slag. The former are drawn from the teeming stage to the stripper building at the south end of the plant, where hot ingots for transport to the Cleveland and Redcar Works are loaded into special hot ingot transfer cars. Ingots for the Britannia and Acklam Works must pass over the British Railways lines and are, therefore, allowed to cool before despatch. For slag removal, a separate railway connection to each furnace and mixer runs under the high level stock bay.

In addition to the comprehensive railway system for the heavy, continuous traffic, a good road system has been provided giving access for lorries, cars and trucks to every building. It is intended that all spare parts and machinery for repairs will be moved by road, to avoid interference with the main traffic flow on the railways, and consequent delay.

Melting Shop Building

This building has a length of 1,083 ft. 4 in. and the three parallel crane bays for the casting cranes, furnace charging machines and stockbay cranes have spans of 75 ft., 65 ft. and 65 ft. respectively, in a building 232 ft. wide. As is invariably the case in an open hearth shop, the longitudinal stanchion spacing is governed by the necessity to bridge over each furnace with a single crane girder ; in this case, the very large furnaces fixed the spacing at 125 ft. The furnaces and mixers have each been arranged in pairs, and between the units of each pair a short crane girder span, in length one third of a furnace span, has been placed. There is a similar short span at each end of the building.

General view of the charging bay with charging box benches and instrument cabin on the right, and dolomite hoppers for fettling machines left centre.

The furnace charging stage is 23 ft. above ground level, and the railtracks in the adjacent stockbay are at 21 ft. 6 in. This latter bay contains, in addition to the charging box bench and a wide trimming platform, four railtracks, of which the two nearest to the bench are for scrap, ore and scale, the third is a running track, and the outer one is for lime and limestone. The charging box benches occupy, apart from gangways at each stanchion, the whole of the 125 ft. opposite each furnace and mixer, each furnace bench holding 33 boxes.

The casting crane girders of 125 ft. span over the furnaces have a total depth of 16 ft. 6 in., and, in order to give sufficient space below the girder for the furnace to tilt, the crane rail is 63 ft. above ground level. This rail height is far too great for the furnace charging machine in the adjacent bay, and, therefore, the girder for this machine is supported on cantilevers from an auxiliary girder of the same depth as the casting crane girder, and coupled to it by a system of links. By this means the charger gantry rail has been placed 11 ft. below the casting crane rail. All the stanchions in the shop are of welded construction, with crane and auxiliary legs of H-section, braced together by horizontal girder battens.

View of the stock bay with charging box benches on the left, scrap ore, and scale wagons in the centre, and lime and limestone boxes on the right.

A prominent feature of the melting shop building is the " Mansard " shape of roof, chosen not only for this shop, but for all the steel buildings on the works. This shape allows the roof glazing to be placed on the steep slope, where it will not only keep cleaner, but is more accessible for cleaning. The huge areas of corrugated sheeting on the sides of the building have been broken up by shallow pilasters formed in light steel framing. These pilasters, with the deep parapets, divide the sheeting into panels ; this effect has been heightened by painting the pilasters and parapets green, while the flat stretches are grey.

Between each pair of furnaces is a hydraulically operated service lift, of 15 tons capacity, with a platform 12 ft. long by 8 ft. wide, running between ground and stage levels. These lifts will handle all the furnace alloy materials, together with bricks, fireclay and materials for furnace running repairs.

On the charging stage, running the full length of the shop in front of the furnaces, is a railtrack, connected to the inclined ramp which leads to the stockbay. By this means, wagons of bricks for major furnace repairs can be placed immediately in front of the furnace, and debris can be loaded up and taken away.

Furnaces and Mixers

Each furnace is designed to produce 2,800 tons of steel per week with a bath area of 830 sq. ft., a maximum bath depth of 4 ft. below floor plate and a contour design to take a charge of 360 tons.

The problem of fuel supplies to the new furnaces presented unusual features, and necessitated a considerable degree of flexibility in their design. When the later stages of the Company's development schemes, now in the course of construction are complete, ample supplies of coke oven gas and tar will be available. The furnaces may then be fired with coke oven gas in combination with either by-product tar or fuel oil. In the meantime, apart from a small quantity of coke oven gas, the only suitable fuel available for the furnaces is oil. The flues, regenerators and uptakes have, however, been proportioned to cope with the larger volumes of gases associated with producer gas firing should this at some future date be desirable. At the present time such coke oven gas as is available is used on the mixers in conjunction with fuel oil, but the proportion of oil can be increased if necessary to provide the whole of the heat to the mixers.

In the dividing wall between the gas and air sections of the regenerators, balancing openings have been provided, which would be bricked up if the change to producer gas were made. The port block brickwork has been designed for oil firing only, but a minor modification in the dog house, with larger burners, will enable a change to mixed coke oven gas and oil firing to be easily and quickly made. If a change to producer gas is found necessary, the whole port block will be re-built on the present substructure. No gas producers have been installed, but space has been left for them behind the furnace building.

The furnace hearth is 50 ft. long by 18 ft. wide inside the lining at foreplate level ; the furnace vessel is 62 ft. long over the chills, and 31 ft. 6 in. wide over the buckstays. The pan conforms in shape closely to the contour of the hearth and is built of plates $\frac{1}{2}$ in. thick. It is supported on ten longitudinal girders, arranged in three groups, a centre group of four girders 3 ft. 6 in deep under the bottom of the pan, and two side groups of three girders 3 ft. deep under the lower part of the pan sides. These girders are of welded plate construction, and are rigidly attached by welding to the two furnace rockers. The rockers have double webs, each 1 in. thick, and to maintain the continuity of the tension sides of the longitudinal girders, the webs are slotted to half the girder depth, to allow the latter to pass through.

The binding system consists of vertical buckstays, made of 18 in. $\times$ 6 in. slabs, arranged in pairs, with top and bottom ends attached to horizontal plate girders. The upper girder forms a platform, 3 ft. wide, round the top of the furnace, while the lower is at charging stage level, and fills the gap between the furnace and the

fixed stages at the charging and tapping sides. The buckstays are also tied across the top of the furnace by straps, and at the bottom are attached to the outer pan supporting girders by diaphragms. The end frames are fabricated from 24 in. × 6in. slabs and 24 in. joists, welded together, the former being used for the horizontal member supporting the bottom chill, and the inner vertical side members. As these three members are all liable to be overheated if the brickwork at the end of the hearth becomes too thin, slabs were used.

The two rockers are 35 ft. apart, giving sufficient room between them for two slag ladle railways. The roller path has a radius of 15 ft. 6 in., and is formed of a steel plate 2 in. thick and 28 in. wide. Each rocker is supported on four 48 in. diameter rollers, mounted in pairs on compensating frames, which transmit the load to the cast steel pedestals, carried on a welded steel bearer girder.

The furnace body can be tilted by hydraulic power at a pressure of 800 lb./sq. in. to an angle of 35° from the horizontal for tapping, and 15° for slagging. The two tilting cylinders at the tapping side of the furnace are 26 in. bore and 20 ft. 3 in. long, and a force of 300 tons can be exerted by the water pressure on the two pistons. Each cylinder is supported on trunnions, carried on cast steel pedestals which stand on the furnace foundation blocks. The piston rods are 12 in. diameter × 28 ft. 7¾ in. long overall, and are connected to the vessel by pins 11 in. diameter. There are two tilting control stations, with valves piped in parallel, one at the tapping side of the furnace, the other at the charging and slagging side.

On the charging side of the furnace are five doors, all of the same size, with openings 5 ft. wide at the top tapering to 4 ft. at the sill, and 4 ft. high. The door frames are water-cooled and completely surround the door openings. Slagging notches have been provided below the second and fourth doors, and the horizontal binding girder on the furnace has been notched to allow the slag to fall through to the slag ladles below. The doors are of cast steel, with brick linings 4½ in. thick. They are arranged to pass the sill when fully lowered, and come to rest against wedges which press them into contact with the door frames, so reducing air infiltration.

Charging hot metal into 600 ton mixer.

On the tapping side of the furnace are two doors each 3 ft. 2 in. wide by 3 ft. high, placed in the shoulder at each end of the back wall. These are for charging mixer metal. On the tapping platform opposite these doors are the launders, which are mounted on bogies, and can be swivelled so that they do not unduly obstruct the platform.

In the building of the hearth, 1½ in. of insulating concrete was laid against the shell plating. On this was laid 4½ in. of firebrick and 1 ft. 6 in. of magnesite brick. The hearth proper is of dolomite to a maximum depth at the centre of 15 in. The backwall is fully sloping, except for a vertical portion 2 ft. high immediately under the roof, which is constructed of 4 in. diameter magnesite tubes. The main roof has a span between walls of 24 ft., a rise of 3 ft. 3 in. at the centre, and a thickness of 15 in. with 18 in. ribs.

Port ends are retractable with water-sealed uptakes. The decision to install this type of port block, rather than a fixed structure with a removable " Friedrich " slice, was governed by the general layout of the shop. As mixer metal is handled in the casting bay, the only lifting equipment over the centre of the furnace is the 10-ton auxiliary crab on the overhead charging machine, which is not powerful enough to lift a removable slice. Moreover, a retractable port block can be pushed right up to the furnace, providing an effective seal between the furnace and port end chills.

Each port block is carried on four cast steel wheels, running on 375 lb./yard rails on the track girders, which are supported on four 22 in. diameter hydraulic rams. For tilting, the port blocks are retracted a few inches only, by means of hydraulic pull-back cylinders. For repairs to the vessel and port block, the block can be lifted about 18 in. to bring the dippers out of the seal troughs, and retracted a distance of about 11 ft. When the block is to be fully withdrawn, two sections of the stage are taken from behind the block, and placed between it and the vessel, to form a working platform. The port blocks are bricked entirely with silica brick, except for the nose of the doghouse, which is chrome magnesite. Two furnaces have port ends with twin uptakes, while the remainder have single uptakes, the area, 81 sq. ft., being the same for both types.

The slag pockets, regenerators and flues are all designed and proportioned so that the furnace can be efficiently fired with producer gas. The slag pockets are 25 ft. long, the larger pocket being 13 ft. 9 in. wide and the smaller 8 ft. 6 in. The floor of each slag pocket is carried on 22 in. × 7 in. joists spaced 24 in. apart, on which is a slab, 18 in. thick, of refractory concrete. Under the slag pocket is a chamber giving access to the bearer flues of the regenerators through stoppered openings in the end wall. Access to this chamber is by two openings in the floor of the casting bay in front of the slag pockets, normally covered by steel slabs. The regenerators have a total checker volume of 11,500 cu. ft. at each end of the furnace. The two chambers into which each regenerator is divided are 30 ft. long, the larger chamber being 16 ft. 3 in. wide, and the smaller 9 ft. 9 in. In both chambers the height of checker brickwork is 14 ft. 9 in. above the bearer arches. Below valve pit floor level the regenerators are in reinforced concrete tanks and above this level, they are plated, with a rigid steel binding, tied at the bottom by horizontal plate girders encased in the concrete, and at the top by a braced system of joists and channels.

Separate air and gas flues have been provided, although with oil firing the two flues will be operated together, and balancing openings have been left in the centre wall between the regenerator chambers. All the flues, from both ends of the furnace, unite into a single flue leading directly to the uptake of the waste-heat boiler, with a by-pass to the chimney. The four reversing dampers are grouped together, close to the junction of the four flues, and are operated together by ropes wound on drums mounted on a single shaft, which is revolved by means of a toothed rack between two opposed hydraulic rams. The whole of the reversing gear is carried on a platform, suspended from the under side of the stockbay stage. Space has been left on this platform for the additional gear which would be required for operating gas dampers if the furnace were converted to producer gas firing. In the flues, too, the brickwork has been built so that a gas valve could easily be added. Combustion air is supplied by a 50 h.p. fan, with a capacity of 30,000 cu. ft./hr., and distribution can be regulated by subsidiary dampers at the back of each reversing damper frame.

Test-tilting 360 ton furnace before laying brick lining.

The two mixers, each with a capacity of 600 tons, have hearths 51 ft. long and 19 ft. 6 in. wide at foreplate level, giving a hearth area of 913 sq ft. actual, and a depth at the centre of 7 ft. They are designed for active working, with a heat input of 570 therms/hr., and can, when supplying the furnaces with about 6,700 tons/week of metal, melt up to 1,600 tons/week of scrap.

The construction of the vessel steelwork is generally similar to that of the furnaces. The pan has a bottom radius of 11 ft., with sides sloping at 48° to the horizontal, and is supported on nine equally spaced plate girders, 3 ft. 6 in. deep. These are attached to the two rockers, 32 ft. apart, in the same way as the furnace girders.

The hearth lining is formed of a thin layer of refractory concrete inside the pan, followed by 4½ in. of firebrick, 18 in. of magnesite brick and 15 in. of dolomite. Front and back linings are nearly vertical: the front lining is of silica, the back is built of 4 in. diameter by 18 in. long magnesite tubes, and the shoulders are of chrome magnesite. The roof brickwork is 15 in. thick, with an 18 in. rib at every fifth course.

On the charging stage side there are five doors, three on the front of the vessel, and two in the tapered ends. The middle and end doors are the same size as those on the furnaces, but the intermediate doors have openings 6 ft. wide at the top, tapering to 5 ft. at the sill, to permit the charging of heavy scrap. Blast furnace metal is charged through the two doors in the shoulders at the tapping side, using swivelling spouts similar to those used at the furnaces for charging mixer metal. One slagging notch is provided under the centre door.

The port ends are of similar design to those at the furnaces, with the same lifting and retracting gear. The twin uptakes are each 4 ft. 6 in. by 5 ft., giving a total area of 45 sq. ft. Mixed fuel burners are fitted, capable of burning coke oven gas and oil, or oil alone.

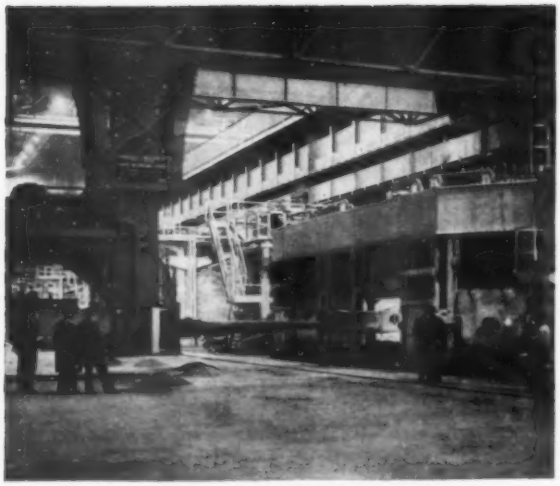
The regenerators have each two chambers, as on the furnaces, with a total checker volume at each end of 7,800 cu. ft. The larger chamber is 13 ft. wide × 24 ft. long, and the smaller one 8 ft. wide, with the same depth of checker brickwork, 15 ft. 6 in., in both chambers. The two slag pockets at each end are 24 ft. long, and are 11 ft. 6 in. and 7 ft. wide respectively.

Between each pair of furnaces or mixers, on the opposite side of the charging stage, is a control station. All the controls, except the hydraulic valves for tilting, port-end retraction, and the tapping side doors, are grouped at this point. These controls are on a sloping desk, behind which is the vertical board for instruments and recorders. Between the desk and the board is a gangway 2 ft. wide, and behind the board an enclosed space gives access to the instruments and their connections. At each end of the instrument board is a cabin 9 ft. 6 in. square for the furnace crew.

Reversal of the furnaces is manual, and on the panel is a reversal indicator, which shows the sequence of operations required to reverse the furnace, with coloured lights indicating when each operation is complete. Temperature indicators and recorders connected to the regenerators give a guide to the furnacemen in reversing.

The furnace and mixer cooling water is a closed system, all the supply and return pipes being under pressure, except for the make-up to the uptake seal trough. From the pumps, a 24 in. ring main is connected to both ends of the shop, and runs along under the stage. At each end of every furnace, branches connect by flexible pipes to the port block coolers and chills, and by walking pipes to the vessel door frames, chills and skewbacks. The return pipes leave the furnace in the same way, the branches connecting to a 24 in. diameter return ring main leading direct to the cooling tower.

The three fuel oil storage tanks are each 40 ft. diameter and 36 ft. high, with a total capacity of 850,000 gal. Road vehicles can discharge by their own pumps direct into the tanks, whilst rail tank wagons, in trains of ten wagons, are discharged in a building adjacent to the storage tanks, through a header pipe with ten connections, by three pumps. This oil passes through three filters, arranged in parallel, each of 4,000 gal./hr. capacity. Each tank is fitted with a float-operated depth gauge, and an air-operated remote reading gauge, with the scale in the pump house. Oil from the tanks passes through the filters and primary heater to the



Charging scrap into 600-ton mixer.

circulating pumps and secondary heater, which send the oil into the 4 in. supply main at a temperature of 240° F. and a pressure of 200 lb./sq. in. The supply and return mains are lagged together with a 1½ in. steam tracer pipe between them. At each furnace control station is a platform, slung from the underside of the stage, and reached by a stair from the stage, giving access to all the valves and fittings below the control desk and instrument panel.

Overhead Cranes and Chargers

The three 75 ft. span ladle cranes in the casting bay are each of 160 tons capacity, with a 30 ton auxiliary crab, and carry a ladle of 120 tons capacity. Three semi-portal teeming carriages, with one rail over the teeming platform and one on the casting bay floor, release the overhead cranes for other duties, including transferring iron from the mixers to the furnaces. The carriages can travel the full length of the shop, and have a cross traverse of 5 ft. 3 in., which is sufficient to allow teeming into two or three lines of moulds set up on the casting cars.

The handling of all hot metal in the casting bay obviates the need for a hot metal crane in the charging bay, and allows the use of overhead revolving charge. These, by keeping the stage clear for the work of the bricklayers and their materials, enable the length of time spent on a general furnace repair to be appreciably reduced. Four overhead charging machines, of 6 tons capacity and 65 ft. span have been provided each with a 10 ton auxiliary trolley. Each machine can charge boxes into the furnace at a rate of one a minute, and the size of the furnace and the length of the charging box benches are such as to allow two chargers to work together on one furnace. Running across the melting shop, over the ladle crane and charger gantries are three 7½ ton crane repair trolleys.

On the four 20 ton high speed magnet cranes operating in the stock bay, the magnets are slung by three chains from a spider, to which are anchored three hoist ropes, wound on two barrels geared together. This method of suspension is designed to eliminate swing of the magnet. Lime and limestone in boxes are stacked in fours on pallets, which can be lifted on to the bench by a special lifting beam which clips on the magnet.

Furnace Raw Materials Handling

A separate building, 270 ft. long, with a crane span of 65 ft., situated on the east side of the melting shop, houses plant for: (*a*) dolomite crushing; (*b*) lime and limestone stocking; (*c*) preparation of mortar, fireclay and tarred dolomite; (*d*) ferro-manganese crushing; and (*e*) storage and handling of anthracite, ferro-alloys, etc. Dust proof enclosures are used in handling the lime, limestone and dolomite.

On one side of the building a wagon tippler discharges railway wagons of lime, limestone or dolomite into a hopper, from which it is raised by twin skips travelling on a combined hoist and runway covering three bunkers, one for each material.

From the storage bunkers, lime and limestone are carried by two further skips, travelling on combined hoists and runways across to two small service bunkers, one for each material, at a high level adjacent to the east side of the stock bay. Each of these bunkers is equipped with a retracting belt feeder, which fills the charging boxes one by one as they are hauled on their wagons past the filling point by a wagon haulage gear fitted between the rails, and pulling on the wagon axles. The available stock in the melting shop, with all boxes full is over 300 tons, and the lime and limestone plant can handle the whole of the melting shop's requirements for the three shifts, while working on one shift only.

Dolomite is fed from its storage bunker into a swing hammer mill. After crushing, a bucket elevator delivers it into a bunker of 90 tons capacity, from which portable bins can be filled by means of a belt feeder. The bins are simply the top hoppers from the fettling machine, enlarged to hold about 4 tons of dolomite. They are carried from the materials handling plant bunker, across to the two furnace stage service lifts, by fork lift trucks of 12,000 lb. capacity.

In addition to the main enclosure of the lime, limestone and dolomite handling plant, extraction hoods are provided at all filling and feeding points, where falling material may be expected to cause a dust cloud, even if the point is already inside the main enclosure.

The remaining furnace materials which are stored and processed in this building are brought in on a high level railtrack, and stored in open bunkers below the rail gantry. For fireclay, mortar and tarred dolomite, three 9 ft. pan mills have been provided. The various ferro-alloys are carried to the stage service lifts by the fork trucks in bins of 3 tons capacity. These trucks also carry fireclay and tarred dolomite in skips, and anthracite, already made up in bags, on pallets.

Basic Slag Plant

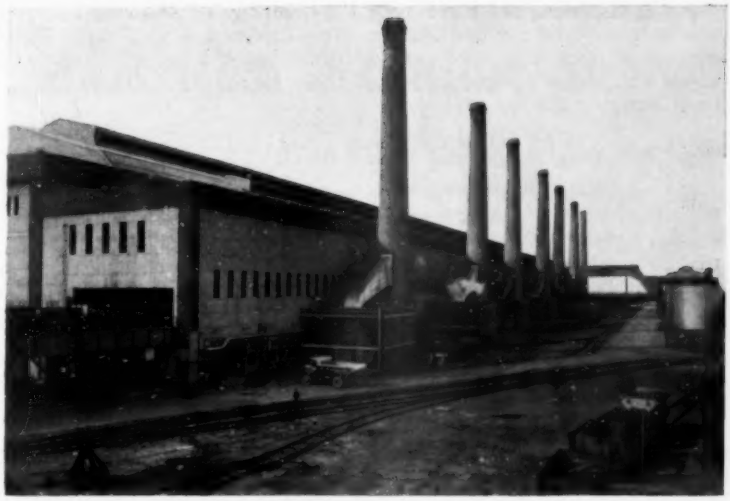
A basic slag crushing and grinding plant, capable of producing 2,500 tons per week of ground slag, will not only grind all the suitable slag from Lackenby furnaces, but will also deal with fertilising slag produced at the Company's other furnace plants.

The slag bank which lies parallel to the melting shop, has a usable length of 1,100 ft. and a tipping height of 18 ft. The furnace slag, brought in ladles of 235 cu. ft. capacity, is tipped progressively along the bank, and allowed to cool and disintegrate.

Sufficient tipping length and height is available to allow the slag to lie for two or three weeks, after which it is loaded by a 1¼ cu. yd. diesel-driven excavator into dumpers, which carry it to the primary hopper. Before being crushed, the slag passes over a roll screen and a

picking table, where steel scrap is picked out and thrown aside for collection and return to the furnaces. The screened and crushed slag is raised by a skip hoist to the crushed slag bunker, of 300 tons capacity, sufficient to allow the crusher to work on one shift only, while grinding takes place on two shifts.

Grinding is done in a compound ball mill of three compartments, after which the slag passes into one of four containers, each of 70 tons capacity where it is held until a sample has been analysed. It is then blown by compressed air either into one of four silos, each holding 900 tons, or to the automatic bag packing machine, which, with one attendant to place the empty bags on to the spouts, can fill and weigh the bags at a continuous rate of 60 tons per hour. Conveyors are installed for carrying the bags and loading into either lorries or railway wagons at the same speed as the bags are filled.



View of the melting shop building showing waste heat boilers and on the right, oil storage tanks with the lime and limestone gantry in the background.

Gas, Steam and Water Services

Coke oven gas to permit of the furnaces and mixers being fired with a mixture of gas and fuel oil, is brought from the Cleveland Works in an underground cast iron 24 in. diameter main, connected at the melting shop to a steel main supported below the charging stage. Gas burners on swivelling arms, for drying out the casting ladles, are attached to the tapping platform stanchions.

The general steam supply, for oil heating and atomising, for space heating in the offices and engineering shops, and for power generation, is raised from twin drum waste heat boilers at each furnace and mixer. Each boiler can generate 12,800 lb./hr. of steam at a pressure of 250 lb./sq. in., superheated to a temperature of 540° F.

Electric power is generated by a 5,000 kW turbo-alternator at 11,000 volts, 50 cycles. Steam from the turbine can be passed out at 35 lb./sq. in for space heating and for heating the boiler feed water. The turbo-alternator is placed, together with the furnace cooling water pumps, in a small power station, which also houses the main works electric substation. Close by is the concrete cooling tower, 100 ft. in diameter, divided into halves for ease of cleaning. The base tank of the cooling tower has a capacity of 500,000 gal., to give a reserve supply of water in the event of a shortage of make-up from the town's main.

For the cooling water service, a common system has been installed, serving both the turbo-alternator and the furnaces. Water from the cooling tower sump is pumped through the condenser by its circulating pump, and delivered direct into the suction header of the furnace circulating pumps which send the water, in a closed system of pipes under pressure, to the furnaces and back into the cooling tower. By this method of operation, a greater pick-up of heat results, with consequent improved efficiency of the cooling tower. There are two electrically driven furnace pumps, each with a capacity of 4,500 gal./min., and a steam turbine driven standby which is automatically started up by a fall of pressure in the delivery main. Provision has been made to compensate for any lack of balance between the requirements of the condenser and the furnaces, and the north or the south section of the ring main can shut off in the event of an emergency.

The hydraulic power for the furnaces and mixers is supplied by three centrifugal pumps, each capable of delivering 300 gal./min. at a pressure of 800 lb./sq. in. Because the demand for hydraulic power by a battery of steel furnaces is very variable, fluctuating within a few seconds from zero to possibly over 600 gal./min., the pumps work in conjunction with an air loaded hydraulic accumulator of 400 gal. capacity, on which the controls will start up successive pumps as required.

The hydraulic pumps and accumulator, the boiler feed pumps and water treatment plant, the furnace fuel oil pumps, and the evaporators for the plant oxygen service, are all placed in a common house to the east of the main plant, and connected to it by a pipe bridge carrying all the service pipes. The house is divided into sections for the various services, and on its flat concrete roof are the two supply tanks, one for boiler feed water and the other for the hydraulic pressure system.

Rolling Stock

As the Lackenby Steelworks is a self-contained plant, it has had to be equipped with a considerable amount of rolling stock for the transport of the various materials along its 24 miles of railway track. All the locomotives are steam driven, two being of the fireless type for use in places where smoke would be a nuisance, such as below the charging stage, where the slag ladles are hauled out from the furnaces.

Four types of wagons have been provided to handle internal traffic: 16 ton steel bodied box wagons, for general use; flat topped wagons, for transferring boxes of lime and limestone on pallets along the stock bay; 40 ton ore wagons; and 25 ton side tipping wagons, for debris. The ingot casting cars are of welded steel plate construction, with roller bearings integral with the wheels, and are designed to carry a maximum load of 80 tons on two axles.

Slag ladles are of 235 cu. ft. capacity, tipping being effected by wire rope from the locomotive, after the carriage wheels have been chocked.

For transporting hot ingots over the Company's link line to the Cleveland and Redcar Works there are a number of special transfer cars, in which eight 4-ton ingots can stand upright. Five of these cars form a train, carrying 160 tons of ingots.

Workshops and Office Block

The engineering workshops have been built with the following in view: the maintenance of the melting and ancillary plant; the construction and maintenance of the universal beam mill; the possibility of future plant on the Lackenby site; and the easing of the load on the maintenance shops in the older works. The site is such as to provide sufficient area for ample extension, and is reasonably accessible by road and rail from the other plants of the company.

The largest of the brick buildings on the Lackenby site is the main administrative block, a three storey building connected with the south west corner of the melting shop by a footbridge from the top floor. Apart from administrative and welfare accommodation, the building houses the works and stage laboratories, with twin pneumatic tube connection to the sampling point on the stage.

Design and Construction

Not only was the whole project conceived, designed and carried out by the technical staff of the Company, but the resources available within the Dorman Long group and its subsidiaries enabled them to undertake the major proportion of the detail design and construction work.

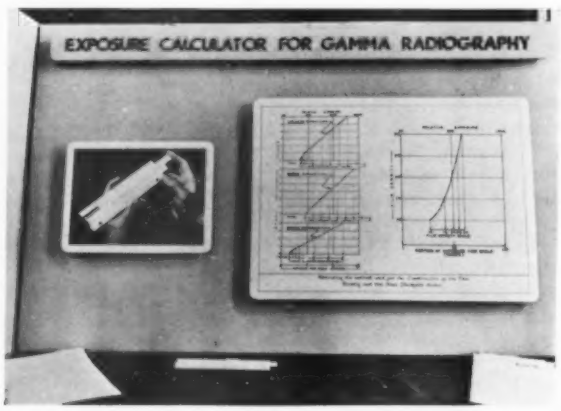
Included in this were the construction of all the main foundations, the design and construction of all the steel buildings, the design of the furnaces and mixers, and the construction of all the steelwork on these units. Among other items manufactured within the Dorman Long organisation were wagons, casting and slag ladles, and all the railway track and sleepers.

The whole of the layout, and, except for cranes and special equipment, the whole of the detail design has been carried out by the Company's technical staff.

British Steel Castings Research Association

First Annual General Meeting and Exhibition in York

THE British Steel Castings Research Association last month held its first Annual Meeting since incorporation as a Research Association in March, 1953, and since it became grant-aided by the Department of Scientific and Industrial Research this year. Following the formal business of the Annual General Meeting, a report upon the Association's work during the year under review was presented by the Director, Mr. J. F. B. Jackson, who had arranged for his statement to be illustrated through the medium of an Exhibition relating to 18 out of the 25 major projects to which attention had been given during the year. Each exhibit was accompanied by the investigator or member of the research staff who had been directly responsible for conducting the work to which the exhibit related, and representatives of Member firms were thus enabled to see the results obtained by the Association, in tangible form, and to discuss these in detail.



In addition to examples of the B.S.C.R.A. gamma radiography exposure calculator, this exhibit illustrated the method used for the construction of the film density and steel thickness scales embodied in the instrument.

The B.S.C.R.A. air feed fettlers' mask, which incorporates goggles for eye protection and an air curtain to enable the wearer to breathe safely in dust-, gas- or fume-contaminated atmospheres, was shown in action on the breathing model seen here.

This 3-dimensional presentation of the Director's Report to Members provided direct evidence of the breadth of research and development activities of the Association, now in its fifth year of operation, and served to emphasise the importance and impact of its recent findings and research results upon industrial practice. It is understood that this Exhibition relating to the Association's work, which was originally intended solely for the purpose of the Annual General Meeting in York, is, within the next month or two, to be repeated in Glasgow, Newcastle, Sheffield and Birmingham, so that all Member firms of the Association will have a further opportunity of arranging for their research and technical staff to see the exhibits and thereby be acquainted with the Association's work, to an extent which the single staging of the Exhibition in York did not, for geographical reasons, permit.

The Institute of British Foundrymen

Fifty-First Annual Conference in Glasgow

An indication of the continued growth of this Institute is the increasing numbers attending its annual conferences, and the present conference was no exception, as the number attending exceeded the figure for any previous meeting. In addition to the business meeting, the social and technical activities associated with the conference were admirably organised and supported ; these involved a very full programme, but in this report it is only possible to deal briefly with the business side of the meeting and the technical sessions.

THE fifty-first Annual Conference of the Institute of British Foundrymen was held in Glasgow from June 22nd to 26th, inclusive. It was organised by the Scottish Branch of the Institute, whose Honorary Secretary was installed as President of the Institute during the Conference. Glasgow is the heart of industrial Scotland and this fact undoubtedly simplified the work of the Committee in arranging, with the co-operation of the respective managements, a series of very interesting visits to important engineering works and foundries in the area. While there is a tendency to associate trade and industry with this city, it should be remembered that it is also the home of romance, and is surrounded by territory as saturated with true romantic lore and legend as any other district. Thus, while the technical sessions and works visits were well supported by the members attending the Conference, the ladies had opportunities of exploring the surroundings, and of enjoying the beauty of the country, despite the unfavourable weather conditions.

The Conference began on the afternoon of June 22nd, with Council and Committee Meetings held in the Central Hotel, while the ladies had tea in this hotel by invitation of Mrs. E. Longden. In the evening, members and ladies were the guests of the Rt. Hon. the Lord Provost and Corporation of the City of Glasgow at a Civic Reception in the City Chambers, George Square, the official welcome being followed by music and dancing.

Business Meeting

The Annual General Meeting was held the following morning in the Rankine Hall of the Institution of Engineers and Shipbuilders in Scotland, with the President, MR. E. LONGDEN, in the Chair. Mr. Longden commented on the great loss they had suffered by the recent death of the General Secretary, MR. TOM MAKEMSON, who, during the past 27 years, had proved himself a great stalwart in building up the Institute to its present position of high repute. The Institute had suffered a grievous loss but the long and efficient service he had given without stint had gained for him a memorable part in its history.

The minutes of the previous Annual General Meeting were read and approved, as was the Annual Report of the Council for the session 1953–54. The statement of accounts was presented by MR. N. P. NEWMAN, the Hon. Treasurer, and approved. It is worthy of note that membership of the Institute has continued to increase, and now stands at 5,300, an advance of nearly 300 in the year. The outstanding occasion of the year was the celebration of the Golden Jubilee of the Institute, which was marked by a special Jubilee meeting and banquet, a Jubilee award, and the issue to every member of a short history of the Institute, compiled by the late Mr. Makemson.

Report of the Technical Council

The twenty-second Annual Report of the Technical Council was presented by MR. A. E. PEACE, Chairman, who emphasised the immense assistance the Council had received from many sources. During the year ending 30th April, 1954, three new technical sub-committees have been formed, and one of the existing sub-committees (T.S.43) presented at this year's Conference an interim report which reviews current developments in cupola practice, and can be regarded as a major contribution to foundry progress. Four other sub-committees have completed their work, three of them having been concerned with the preparation of an atlas of photomicrographs of all cast metals : there can be no doubt that, when published in book form, it will be a unique contribution to the study of metallography. The three new sub-committees formed during the year are studying non-ferrous surface finish ; the feeding of castings ; and the present position of foundry melting coke, with particular reference to the effect of coke quality upon metallurgical reactions. Other work in progress includes ingates ; internal stress ; flow of metal ; cast iron tests and specifications ; copper-base alloy castings ; mould drying ; cupola receivers ; non-ferrous quality test ; and mould materials. In addition to an expression of appreciation to the members who have taken part in the work of the Technical Council and its sub-committees, Mr. Peace paid tribute to the assistance of DR. A. B. EVEREST, who did not stand again for nomination as Vice-Chairman because of heavy duties he is undertaking in another sphere of the Institute's work.

Presentation of Awards

In recognition of outstanding work in the interests of the foundry industry, many awards were presented at this meeting. The President, presenting the 1954 Oliver Stubbs Medal awarded to MR. E. M. CURRIE, referred to the long and enthusiastic service Mr. Currie had given to his fellow members of the Institute in the practice and theory of foundry work and, in particular, of his energetic chairmanship of Sub-Committee T.S.35, which was responsible for the production of the film : " The Flow of Metal in Moulds." Unfortunately, Mr. Currie was unable to be present at the meeting, and the award was handed over to MR. JOHN CAMERON on his behalf. Mr. Cameron fittingly acknowledged the great honour and said that Mr. Currie would take the earliest opportunity of expressing his personal appreciation to the Council and members for this award.

On the recommendation of the assessors, the Council awarded the E. J. Fox Medal for 1954 to Mr. Frank Rowe, in recognition of his outstanding services to the foundry industry over a period of many years. In making the presentation, the President referred to his early association with Mr. Rowe, and said he had pioneered many important developments in British foundry practice, particularly in steel and bronze founding; he had given wholeheartedly of his leisure time for many years to the furtherance of progress and efficiency in British foundry practice. In acknowledging the honour conferred upon him, Mr. Rowe said he was conscious at times that he should do more to try to advance the prestige of the foundry industry, but what he had been able to do had given him great pleasure which was added to considerably by this award.

The Council awarded the Meritorous Medal for 1954, to Mr. W. G. Mochrie, for the exceptional services he has rendered to the Institute as Honorary Secretary of the London Branch since his appointment in that capacity in 1949. The president made the presentation and Mr. Mochrie suitably replied.

The British Foundry Medal and Prize of £10, given annually to the author of the paper adjudged to be the best presented to the Institute during the preceding year, was awarded to Mr. D. H. Potts of the Bristol Branch, in recognition of the excellence of his paper entitled "Pressure Cast Aluminium Pattern Equipment."

As a result of recommendations from branches, the Council awarded diplomas to the following authors of papers read at branch meetings during the past session, or presented at the last Annual Conference:

Mr. E. Morgan for his joint authorship of the paper, "Investigation on Dust Problems in Foundries," presented to the East Midlands Branch.

Mr. D. Fleming for his paper, "Inter-Relation of Combustion and Metallurgical Reactions in the Cupola," presented at the Blackpool Conference.

Mr. A. Emerson for his paper, "Shell Moulding of Cylinder Castings," presented to the London Branch.

Mr. J. Langham for his paper, "Propeller Manufacture," presented to the London Branch.

Mr. C. K. G. Wallwork for his paper, "An Approach to Foundry Mechanical Handling," presented to the Birmingham Branch.

Mr. J. Burrell for his paper, "Quantity Production of Engineering Castings," presented to the Lincolnshire Branch.

Mr. J. Steele for his paper, "Thermit Casting," presented to the South African Branch.

Election of Officers

The retiring President, Mr. E. Longden, after referring to the career of Mr. John Bell, nominated by the Council as President for the year 1954–55, and unanimously acclaimed by the members, and after speaking of him and his work in the interests of the Institute, invested him with the chain of office. Mr. Bell, who has gained a wealth of experience in the foundry industry in his long career, is very well-known and respected by the members of the Institute. He said he regarded it as a very great honour to serve in the capacity of President, and members could be assured that he would do his utmost to maintain the high standard set by his predecessors in office.

Dr. A. B. Everest and Mr. H. J. V. Williams were nominated by the Council as Senior and Junior Vice-Presidents, respectively, and were unanimously approved by members and invested with their chains of office, while Mr. N. P. Newman, J.P., was re-elected Hon. Treasurer. Mr. George Lambert was appointed Secretary with the unanimous approval of the members.

The result of the ballot for the election of Members of Council was announced as follows: Messrs. E. M. Currie, H. G. Hall, M. M. Hallett, R. L. Handley and A. E. Peace.

Presidential Address

Following some interesting personal introductory remarks, Mr. Bell made a very practical approach to some of the problems associated with foundry personnel, and he warned workers in the industry that if this country were to recover and maintain its premier position in foundry production, craftsmen well versed in all its techniques must be available. We might be familiar with the composition of the metal for a particular casting; with the manner in which the mould should be made, with appropriate runners and risers; and with the right mixture of moulding sand and satisfactory venting arrangements; but unless there was someone who, by his experience, could apply them in a practical form to produce a sound casting, the knowledge was of little value. With this in view, Mr. Bell thought much more might be done by the Institute to encourage those whose duty it was to use the tools. He emphasised that of those who started an apprenticeship in the laboratory, the patternshop, or the foundry, possibly only one out of twenty would eventually reach and hold a higher executive post. The others would continue thoughout their working years to be works chemists, patternmakers, or moulders. Whilst the two former activities involved experience of great help to the moulder, production responsibilities were primarily his; and failure of a moulder to produce sound castings jeopardised not only his own industrial future but also that of his employers.

Mr. Bell emphasised the importance of new ideas, but if these came before there was a need for them, those who produced them might feel frustrated. He cited the case of alloy castings, which were thought of many years before they became a practical proposition. Thus, he thought that the most powerful force for progress was "an idea whose time has come." Undoubtedly the idea was important, but so also was the time for its arrival. At this stage, Mr. Bell emphasised a point that he had made earlier in his address—the importance of those whose duty it was to translate the idea into accomplishment. It was important to know what was to be done: it was no less important to know how to do it.

The Edward Williams Lecture

A very interesting and informative lecture on engineering research methods and casting problems was given by Professor A. W. Scott, who is Associate Professor in the Department of Civil and Mechanical Engineering at the Royal Technical College, Glasgow.

Referring to the desirability of closer collaboration between the engineer and the manufacturer of castings with the object of improving designs and reducing manufacturing costs, Professor Scott said that apart from studying more closely the stresses imposed on his castings, there was no doubt that the engineer could materially improve his designs if he fully understood those actions in the casting process which gave rise to adverse effects on the metal. Whilst it was no part of the normal technical training of engineers to study the

physical, as distinct from metallurgical, aspects of the casting process, there were, nevertheless many problems in engineering design which involved factors similar to those encountered in casting. These had been studied theoretically and by experimental research, and there was no doubt that those engaged in the respective fields could benefit from a study of each others methods of approach.

The competent appraisal of all the complex problems of casting design and production were beyond the scope of such a lecture, or indeed of a single lecturer, said Professor Scott, but there were many problems of engineering and casting which involved heat transfer, and stress effects due to thermal, residual and external forces, and it was to such aspects that the lecture would be confined.

All the effects concerned in the casting process were a direct consequence of the heat transfer from the metal to the mould material, and thence to the surroundings, and there was little doubt that if it were possible to control completely the rate of heat transfer in various parts of the mould, most casting troubles would be eliminated. Professor Scott then discussed the study of unsteady heat transfer problems by calculation, which necessarily involved the experimental determination of the thermal properties of the materials concerned. More was required to be known about the basic heat transfer actions within a freezing mass, and the suggestion was made that useful basic data might be obtained by a study of the freezing of liquids less complex than molten iron or steel. Some exploratory work had been carried out at the Royal Technical College on the freezing of 6 in. spheres of water and benzene, and the technique seemed to have possibilities.

The more complex problems of the stress distribution in solids arising from temperature variations had not yet been subjected to the same exhaustive theoretical and experimental examination which related problems in the field of heat transfer and strength of materials had received. It was interesting to note, however, that the study of thermal stressing had recently been forced on two branches of engineering founded on the scientific approach. In the design of atomic energy reactors, the high rates of heat release involved had given rise to acute thermal stressing problems, whilst the increasing speeds of aircraft had, likewise, introduced new problems of this type, due to kinetic heating effects at very high speeds. After discussing the stress effects which could result from heating a solid, Professor Scott said that in the case of cooling castings the temperature gradient developed across the wall would induce thermal stresses, and the volume strain at the solidifying edge, due to change of state would cause further stresses. Really serious stresses would, however, only develop as the material gathered strength and marked temperature difference developed in the casting. If the temperature distribution in the casting were known beyond the stage when solidification was completed, it would be a relatively simple matter, apart from stress concentration factors, to calculate the additional thermal stresses set up after this stage during cooling. The real difficulty would be in assessing the stresses that had been developed prior to complete solidification.

Technical Sessions

Some fourteen papers were presented at this Conference, in addition to an Interim Report of Sub-Committee T.S.43 on cupola developments, and the resulting discussions were both interesting and informative. In one instance—the production of heavy steel castings—the paper was supported by a very interesting film. There were six sessions and the number of papers presented at any one session did not exceed three, which, in most cases, gave reasonable time for their discussion, but, to enable discussions to take place in the limited time, the usual practice of holding two sessions simultaneously was again adopted. The exchange paper from the American Foundrymen's Society was on the application of the Dietert process of moulding in the foundry, while that from the Sveriges Mekanförbund was on Swedish practice in correlating the properties of castings in grey iron. The subjects discussed covered quite a wide range, but they concerned mainly the ferrous side of the industry.

It is not possible to present a complete report of the proceedings at these sessions, through lack of space, but brief summaries of the papers and of the Report will be of interest and are given below.

CUPOLA DEVELOPMENT

First Report of Sub-Committee T.S.43 of the Technical Council

There can be no doubt that the cupola will remain the standard melting unit for cast iron for many years to come, and recent technical advancements have indicated that its value can be increased. This Report is mainly a review of existing practical experience in Britain. Emphasis is laid on results achieved rather than upon details of operation.

British performance data on the hot-blast cupola have been lacking in the past, and the results given in this Report are those being currently obtained using up-to-date equipment. It is shown, for instance, that hot-blast cupolas give scope for fuel economy, and efficient operation becomes less dependent on coke quality. When fuel economy is practised, satisfactory metal temperatures are obtained with some gain in carbon pick-up, a reduction in silicon loss and a lessened pick-up of sulphur. Where coke saving is of less concern, hot-blast operation with normal coke quantities gives higher carbon pick-up, permitting greater use of steel scrap in replacement of pig-iron in the metal charge. When no reduction is made in the coke charge and extra steel is used, no significant reduction in the extent of sulphur pick-up can be expected in acid practice.

Heat-exchange units, with ancilliary equipment, now available for pre-heating the blast to 500° C. are proving satisfactory in service, and show a considerable improvement over earlier designs. Delay in the extension of the use of hot blast in this country has been due mainly to the high installation cost, and doubt as to whether the capital expenditure would be justified. It would appear from this Report that the savings which might be effected in coke consumption alone are unlikely to justify the high installation cost. Economic advantages, however, are more apparent in the replacement of pig-iron with steel scrap and ferro-silicon, while the present price differential between the two former constituents of the charge prevails. The extent of the influence of hot blast on carbon pick-up reported enables an estimation to be made of the savings to be anticipated in the metal charge, and also the cost effect of lower loss of silicon.

The economic advantage of hotter metal depends on the class of casting being produced, and is a matter for

each individual foundry to assess. Having made an assessment of the savings in metallic constituents and the added operating costs, then the pay-off period for the equipment will be determined by the estimated throughput of the unit in a given time.

Methods of water cooling applied to acid-lined and basic-lined cold-blast cupolas have been investigated, and extensions of previously published work have been made available to the sub-committee. It is apparent that a wide field of investigation is open on the subject of water cooling, and further progress has been made. Reference is made to the use of protruding water-cooled tuyeres, which are claimed to have the advantage of reducing the quantity of water required with lessened dissipation of heat. Application of water cooling to the basic-lined cupola offers a possible solution to the lining problem, and further work in this direction is strongly recommended. The combination of heated blast and water cooling is attracting attention, and the results obtained from a unit combining these modifications are reported.

Ability to carburise scrap charges to a greater extent than in conventional practice is an accepted requirement of the industry, particularly for those foundries producing castings in low-phosphorus iron. Means of increasing carbon pick-up would give relief during periods of pig-iron shortage, and could be economically attractive at current raw material prices. Apart from the effect on carbon pick-up of hot-blast operation, it has been established that melting under the influence of basic slag will result in carbon pick-up together with decrease of sulphur. Data produced by various workers in this field are tabulated, and the results obtained in a comprehensive range of cupola mixtures from all steel and iron scrap to all pig-iron are reported. This series clearly demonstrates the considerable increase in carbon pick-up which can be obtained with basic slag operation and that the carburising effect under such operating conditions is complementary to desulphurisation.

The sub-committee state that the sources from which information has been drawn have proved somewhat limited, and a continuation of the work will be helped considerably if more active work is undertaken by individuals and firms and the results made available. It is certainly hoped that the Report will attract more workers into this field of investigation.

DESIGN AND OPERATION OF A MODIFIED CUPOLA

By F. A. Woolley, A.I.M.

Following experimental work on a cupola, which involved the application of a form of resistance heating to the cupola well and its contents, the lower part of the cupolas in the foundries of a large manufacturer of cylinder block castings were converted into resistance units. Electrodes were inserted horizontally through the walls of the well, so that a heavy electric current could be passed through the well against the resistance of its contents. By this means a source of heat is provided which, being independent of the heat generated in the normal melting zone higher up the furnace, can be used to correct irregularities that may develop in that zone. The quantity of heat so provided is controlled by varying the power input.

In addition to providing a convenient and rapid method of temperature control, the experience gained suggests that the additional heating so applied has important effects upon both the composition and the casting properties of the metal tapped. The indications are that chemically-reducing reactions between oxides that collect in the slag and the excess of carbon present in the coke, are stimulated, and slags low in iron oxides result. Metal under such slags shows a reduced tendency to " throw " chill, and appears to be able to yield a greater pick-up of carbon. With heavy input of power, evidence of a positive increment in silicon has been obtained. The use of this modified cupola has been found to improve the service of metal to the pouring stations in the foundry, and to widen the range of raw materials that it has been possible to utilise at times when the supply of these materials has been a major problem.

This method of applying auxiliary heating to the well of the cupola has been operating under service conditions for several years, and it has proved quite a practical tool, particularly in smoothing out any irregularities that occur during melting.

CUPOLA PRACTICE: SECOND THOUGHTS

By W. Y. Buchanan

In 1935, the author gave details of the installation and performance of a 45-in. " balanced-blast " cupola, in a paper before the Scottish branch of this Institute, in which he said that the furnace would hold its place for the next 20 years in face of competition from rotary furnaces. In the present paper he reviews the position after the 20 years has expired. No revolutionary principles in cupola design have been introduced during this time, so far as tuyere arrangement is concerned. Hot-blast has been revived, in some instances, in addition to basic linings and water cooling. These innovations have their successful applications, but each foundry must be carefully considered in the light of its own set of circumstances.

In the present paper the author gives some operational details and explains some of the changes which have been introduced, mainly to auxiliary equipment. He discusses cupola linings, water cooling, basic linings, continuous runners, ladle covers, tuyeres, coke, air weight regulation, slag disposal, the charging platform, a pneumatic concretor, a movable platform for repairing the inside of the cupola, patching material, and spark arresters, and since, in some respects, his views constituted a challenge, it is not surprising that the resulting discussion was a lively one.

THEORY, ECONOMICS AND PRACTICAL APPLICATION OF EXOTHERMIC MATERIALS

By D. V. Atterton, M.A., Ph.D. and C. Edmonds

Since all casting metals and alloys contract on cooling from the temperature at which they are cast, feeding is necessary to ensure that additional metal is supplied as shrinkage takes place. Ideally, the contraction on cooling down should be reflected by a fall of the liquid metal in the feeder head, but " skulling " of the surface of the feeder head often occurs at a comparatively early stage. Apart from the obvious disadvantage of preventing the application of atmospheric pressure to the liquid feed metal, this " skulling " leads to the enlargement of cavities due to solidification shrinkage by an amount corresponding to the liquid shrinkage.

Several foundry and experimental methods are described that have been developed with the object of ensuring a sound casting with the minimum size of feeder head. It is indicated, by means of a number of examples, that the surest way by which casting yields of the order of 90% may be obtained is to introduce heat into the feeder-head metal, and/or to insulate it to a very high degree, preferably by means of a hot, low-thermal-conductivity sleeve. The relative merits of two such methods—the thermit-type material and the mouldable exothermic material—on steel castings are discussed, and a brief account is given of the application of these two methods. Several possible ways of considering the costing of the use of exothermic materials are proposed; it is suggested that, in addition to the direct value of the melting cost of the metal saved, less the cost of the exothermic material, consideration must also be given to other factors, particularly to the resultant increase in foundry output. In conclusion, the authors describe typical castings that have been produced with the aid of exothermic sleeves.

MODERN PRODUCTION OF WHITEHEART MALLEABLE IRON

By Jeffrey Bernstein, A.R.I.C., A.I.M.

In this paper the author describes the changeover from a standard range of castings, $\frac{3}{32}$ in. to 1 in. thickness, weighing from 7 g. to 14 lb., and annealed in ore in a coal-fired furnace, to a wider range and increased output of malleable-iron castings weighing from 7 g. to over 4 cwt., annealed in controlled-atmosphere electrically-heated furnaces. The production plant, comprising moulding machines and sand mill, is briefly described, as also is the pattern work, which is primarily of brass and iron set on cast iron plates, and sometimes involving the use of stripping plates. The coreshop, which may be required to provide 24,000 cores per day, is equipped with two oil-fired core stoves, which operate at different temperatures and speeds according to the type of core and core-sand mixture. Twin, balanced-blast cupolas, lined down to 27 in. diameter, comprise the foundry melting equipment. Between 72 and 80 charges, each of 400 lb., are melted daily, the composition of the charge being altered according to the type of work being cast. Several charges of different composition may be melted in between the standard charges for the day, to coincide with the time that a particular mould or group of moulds is ready for pouring. The metal coke ratio is approximately 7 : 1. The charges are based on standard figures for a particular section thickness, and these are based on chemical compositions which will yield the required properties in the material after a specified annealing cycle.

The decarburising atmosphere in the electric annealing furnaces consists initially of a mixture of air and water vapour. To effect adequate decarburisation of heavy sections, advantage is taken of the fact that, at the annealing temperatures employed, the carbon is in solid solution in austenite, and that rapid cooling from this state to a temperature of approximately 700° C. will promote the precipitation of iron carbide. This will form fine spheroids of cementite in a ferritic matrix, if this temperature is maintained for a period and then followed by a cooling rate of 5–10° C. per hour for periods from 6–15 hours, according to the type of casting. The whole process is under laboratory control. A question that would appear to remain is whether a material of 3·25% total carbon and 0·35% silicon, which is annealed to yield a homogeneous micro-structure of finely spheroidised cementite in a matrix of ferrite, can truly be described as whiteheart malleable cast iron.

METALLIC-ARC WELDING OF SPHEROIDAL-GRAPHITE CAST IRON

By F. A. Ball, B.Sc., and D. R. Thorneycroft, B.Sc., A.I.M.

The welding of normal grey cast iron has always been considered primarily from the standpoint of the reclamation and repair of unsound or damaged castings. It is probable, however, that spheroidal-graphite cast iron will be used in the field of general engineering, and its usefulness for fabrication purposes will be further enhanced if component parts can be joined by a welding process. This may call for new techniques and welding materials in order that the strength and ductility of the welded joint approach those of the parent metal.

The authors have made a study of the metallurgical changes which spheroidal-graphite cast iron undergoes as the result of welding, and how these changes, together with the mechanical properties and the machining characteristics of the welded joints, are affected by subsequent heat treatment. This paper presents an account of the testing procedures adopted, and the results obtained, in the examination of joints welded with nickel-iron and aluminium-bronze electrodes.

It is shown that the mechanical properties of joints welded with nickel-iron electrodes do not reach those of the parent metal, those in pearlitic iron being somewhat lower in strength, and those in ferritic iron lacking some ductility. The thermal disturbance due to welding results in the formation of a narrow hard zone in the cast iron adjacent to the weld metal which causes difficulty in machining. Heat treatment after welding improves the machinability. Hardening will occur in any arc welding operation in which fusion of the cast iron takes place. It was hoped that the formation of this hard zone would be restricted by using the aluminium-bronze electrode, but conditions at the weld junction were worsened by the formation of a layer of hard brittle iron-rich constituent, in addition to an underlying hard zone in the cast iron. The authors made some experiments with a method using a carbon-arc welding technique and an aluminium-bronze filler wire. The preliminary tests showed the method to be difficult to apply, but the occasional success achieved led the authors to feel that the technique warrants further attention.

"D" PROCESS FOR PRECISION CASTINGS

By H. W. Dietert

While all the technical sessions were exceedingly well attended, the interest shown in processes for the production of precision castings was indicated by the large attendance of members to hear Mr. Dietert, who had made a special journey from the United States to present his paper in person. In his opening introduction to the subject, he said that a need for precision castings exists, as indicated by the fact that, in the States, over £1 million worth of castings were made by precision processes in the last twelve months. That covered quite a lot of castings, particularly as the precision-casting methods available at the present time are mainly for small castings weighing under 25 lb., although several

operations are in production where precision castings up to some 200 lb. are made.

The need for precision castings is not so much due to their nice appearance as to the means they offer of reducing the number of machining operations. Mr. Dietert enumerated the advantages of precision casting, but also mentioned some of the problems facing the founder adopting the technique, and stated that precision casting methods are still in a stage of rapid development. The principal methods in use are: (1) investment; (2) shell moulding, " C " (Croning) or " D " (Dietert); (3) carbon mould " G " (Griffin); (4) ceramic mould; (5) plaster-of-Paris mould; (6) precision dry-sand mould; and (7) high-pressure moulding. These he briefly explained.

The " D " process as used today employs an accurately machined metal pattern mounted, with gates, on a metal blow-plate, which in turn is bolted to the blowing chamber of a coreblower. A hot or warm metal core carrier, which is contoured around the pattern surface leaving a small space, usually $\frac{3}{8}$ in., for the core sand is placed under the pattern. The two are clamped together by the coreblower and the core-sand is blown through blowing holes in the patternplate into the space between the pattern and the drier. The pattern is cold and the drier is hot. The carrier with the blown shell mould is then placed in the core oven and baked. The baked shell is removed and two shells are clamped together, forming a rigid mould. Moulds are poured either vertically or horizontally as chosen, allowed to cool from 30 seconds to 3 minutes and then the casting is removed. The burnt sand may be reclaimed.

Since preparing the paper Mr. Dietert has modified his method of bonding the sand for blowing, which should be as dry as possible to prevent sticking. He has found that a previously prepared sand, bonded with resin, can be used successfully with a moisture content as low as 2%. This prepared sand is marketed in the States, although the cost is relatively high. It may be economical to prepare it in the foundry and store it in a dry condition ready for damping down for use.

Mr. Dietert considers that the number of castings made by precision casting methods will steadily increase. It is profitable to make castings by a process that produces them in a condition requiring the least amount of additional labour to convert them into finished components. Such castings are worth considerably more than inaccurate castings and they will put into the foundry a greater monetary flow.

DEFECTS IN VITREOUS-ENAMELLED IRON CASTINGS

By E. R. Evans, A.I.M.

In this paper the author discusses defects responsible for the rejection of vitreous-enamelled cast-iron components. He tabulates them mainly as: (*a*) blistering due to faulty cleaning and filling of holes; (*b*) rippling, colour variation, and blistering due to enamel application faults; (*c*) " crawling," " burning," and scumming due to drying and fusing faults; (*d*) chipping and crazing due to rough handling and poor design; (*e*) " rat-tails " due to the nature of the foundry sand; (*f*) sinks which can be eliminated by coring out thick sections; (*g*) holes due to sand and slag inclusions and blows; (*h*) warping and cracking mainly due to poor design; and (*i*) sub-surface oxide inclusions in the iron, some of which are due to the presence of primary graphite.

Most of these defects can be eliminated or reduced by improving control of materials and techniques throughout the plant. Blistering and its developments, pinholing and black-specking, are due to gas evolution at the surface of the casting. The blister gases are oxides of carbon formed by interaction of graphite and iron oxide formed during the pre-fusion period, or between graphite and sub-surface oxide inclusions, or between graphite and oxide constituents of the enamel itself.

The volumes of blister gases evolved are dependent upon the intimacy of contact between the reactants at the temperature most favourable for the reaction to occur. This contact is dependent upon graphite size and distribution, and the time for which and temperature at which the casting is exposed to oxidising atmospheres at all stages from the mould until enamel fusion commences in the final operation.

The graphite size is influenced by composition, melting temperature and casting temperature. Annealing can be an aid to cleaning in the case of castings contaminated by grease or surface rust, but, whereas this may be an advantage for fine graphite irons, it is not advisable for coarse graphite irons, since oxide penetration will occur.

Long storage periods should be avoided, because of the danger of rust penetration which, once it occurs, is liable to cause trouble unless it is removed by surface grinding or some similar operation.

DIE-PRESSING OF GUTTERS

By R. S. M. Jeffrey, B.Sc. and J. A. Richards

In the introduction to this paper the authors outline the motives leading up to the adoption of machine casting and the limiting factors involved, and then discuss their early experiments. The use of permanent moulds for the gutters was first tried, but, as expected, not only were the castings white but they fractured in many places. To overcome these difficulties it was necessary to remove the gutters from contact with the mould almost immediately after casting, and down-gates must be dispensed with. The only solution appeared to be a displacement casting process utilising fast moving dies. It was decided to try pressing out the gutter by the process which the authors describe very fully. In addition to the machine which they have developed, the production control features are discussed in detail, and metallurgical aspects of the new method of manufacture, which has achieved such remarkable success, are also considered.

SIMPLE FOUNDRY EXPEDIENTS PROVED WORTHWHILE IN RECENT YEARS

By J. E. O. Little

It can be said that many practices that have become standard in a number of trades are the developments of expedients initially introduced. Expedients are particularly common in the foundry, and Mr. Little has done a useful job in bringing some of these to the notice of foundrymen generally, and in suggesting that a compilation of expedients from a much larger number of foundries would provide a mass of useful hints and become a valuable asset on any foundryman's bookshelf.

Simple ideas are frequently adopted to improve details of practice; they are often small, individually, but when collected together they have a total value which is sometimes not appreciated.

Mr. Little has made a collection of ideas taken from the foundries of two firms—Glenfield & Kennedy and

J. W. Blakeborough & Sons. Some of the ideas given arose because existing equipment was called upon to handle increased output, or had to be adapted to suit the working of a mechanised plant. In some instances accident prevention promoted the adoption of simple innovations.

Some eighteen examples are given, including a dummy tap-hole; a protection for drop-bottom doors of a cupola; the use of oxygen in a coke-fired crucible furnace during the superheating period, when melting a high-chromium iron; the use of a turnover chill mould for making hangers; the use of a split chill mould for casting chilled rollers; a special refractory to resist superheat in an oil-fired rotary furnace; the use of a small percentage of molasses in the oil-bonded core mixture to hold the core sand long enough after casting and make possible its recovery; a simple take-off arrangement for pin-lift moulding machines; reducing the cost of metal patterns for impellers; making a pebble-dash pattern for the end-frame of a rotary strainer; the use of hollow castings as dressing stools; the use of rollers for decoring long cylinders; tip-up ends on roller conveyors arranged to meet a power-driven conveyor; modifications to a tumbling barrel, including the use of old lorry tyres inside the barrel; and the use of a rubber conveyor belt strip to prevent sticking.

PRODUCTION OF HEAVY STEEL CASTINGS

By S. Taylor

The trend in the design and use of modern rolling-mill units, forging and extrusion presses and the like, indicates the demand for larger and heavier steel castings, and the steelfounder is being called upon to produce castings of a size and weight never before contemplated. Prior to the war, the largest steel castings made were in the region of 120 tons; more recently press castings of 185 tons delivered weight have been made, and one of these—a crosshead beam casting—is described in this paper. This gave some idea of the immense undertaking necessary to organise the plant, prepare the cores and mould, and cast such large structures. A much better idea, however, was given by means of a film, shown by courtesy of English Steel Corporation, which was very much appreciated by the large attendance of members present. Those responsible for making this film are to be congratulated on its excellence.

PINHOLE POROSITY IN BRASS AND GUNMETAL CASTINGS

By N. B. Rutherford, B.Sc., A.I.M.

One of the most frequent forms of surface defect found in castings to be used for plumbing fittings and the like is pinhole porosity. Industrial experience has shown that this defect can occur in the types of leaded brasses used for plumbing fittings and also in the leaded gunmetals, although lead-free gunmetals seem free from the trouble. This paper describes some experiments carried out in an effort to determine the factors causing pinholes, with a view to overcoming the trouble. The results of the investigations indicate that pinholing in brass and gunmetal castings is a form of severe metal/mould reaction, resulting from the use of wheat flour as a mould dressing or additive. The defect occurs on castings ¼ in. thick at temperatures above 1,160° C. Lead-free gunmetals are, for practical purposes, immune from pinholing, although it can occur to a severe extent in leaded gunmetal, being increased by the presence of phosphorus. The reaction, and the subsequent pinholes, may be prevented by spraying the mould with aluminium/magnesium paint, but this does not give as good a cast surface as the wheat flour dusting. The incorporation of ½% or more pelleted pitch in the facing sand is almost equally effective in preventing the reaction. Pitch gives as good a cast face as the wheat flour, together with ease of stripping. Protection and satisfactory surface appears to be given by several proprietary mould coatings, including a sodium-silicate-water mould dressing and a synthetic-resin-water mould dressing.

CENTRIFUGAL METHOD OF METALLURGICAL RESEARCH

By R. V. Riley, Ph.D. B.Sc., F.I.M. and B. T. Gillyatt

A practical laboratory centrifuge, developed by the authors of this paper, is described. The machine was designed to enable cast iron to be melted, maintained in the molten condition and allowed to solidify whilst still under the influence of a mean gravitational force, equivalent to 1,000 times gravity. This means that the effective weight of one pound of iron in the centrifuge was about half a ton.

The experimental details and temperatures recorded during a typical melting and centrifuging experiment with this apparatus are given. Temperature measurements were made throughout the experiment so that cooling curves could be plotted. On the completion of the run, the solid specimen was removed for a full metallurgical examination. Chemical, spectrographic and gas analyses were carried out, together with microscopic and macroscopic examination, and a longitudinal cross-section of the ingot was sulphur printed.

With the aid of this equipment, investigation was made into several fundamental aspects of the metallurgy of phosphoric grey cast irons. The action of high pressures upon the iron during solidification resulted in a proneness to carbide formation, especially in the form of "inverse chill," and hard spots. The agglomeration of phosphides was observed due to the combined influence of high pressure and thermal currents. In the light of the results, the authors express some views upon the nature and distribution of sulphides in iron. Observed differences in the graphite structure and grain size have been studied. Changes in gas content occurred due to the centrifuging, but these were relatively small. The results are reviewed from both theoretical and practical points of view.

CORRELATION OF THE PROPERTIES OF CASTINGS AND TEST-BARS IN GREY CAST IRON

By Erik O. Lissell, M.Sc. and Morris Itzel, Met.Eng.

Due to the pronounced section-sensitivity of cast-iron, and unknown or unpredictable cooling-rates in the different sections of most castings, absolute relationships between castings and test bars can never be established. Approximations acceptable for simpler castings have, however, been worked out, and are today widely used. The fundamental principle in most specifications has been to cast test-bars of such a design and dimensions that they will solidify with approximately the same structure as the controlling section or main cross-sectional thickness of the actual castings.

From a designer's point of view, the American standard specifications are very simple. It is only necessary to

decide which grade to specify and the calculations are based on this figure: it is then up to the foundry to make the casting in an iron which will give the desired strength in a test-bar corresponding to the ruling section of the casting. For the British designer, the problem is first to find the test-bar, which corresponds to the main sectional thickness of his casting, then to look for the grade which according to the tables will give the desired strength in the bar. His choice of grade will be correct only if the corresponding nominal test-bar to casting relationship is correct, on the one hand, and also the corresponding nominal test-bar to the 1·2 in. diameter "grade-designating" test-bar relationship on the other.

The tentative Swedish specifications call for one single test-bar to be cast under closely controlled conditions and machined to a standard tensile-test specimen of set dimensions. The ultimate goal is to make cast iron testing as uniform as possible, irrespective of the particular foundry, and thus to ensure that the different grades of cast iron are identical throughout the country. It is, however, not only important that the various foundries should produce irons of controlled quality to fulfil certain specifications, but equally so that the designer should know which one of a number of grades of specified irons to use for his castings. The Swedish Grey Iron Standards Committee has therefore worked out a data sheet giving the minimum strength to be expected in various sections of actual castings for each of the standardised grades. Since only one test-bar is used to designate the iron, the approach to the problem of correlating test-bar and casting properties has been somewhat different from that used in other countries.

SOLUBILITY OF HYDROGEN IN IRON CARBON ALLOYS

By B. G. Davies, Ph.D., and T. Evans, F.I.M.

This paper records the results of a study of the effect of carbon on the equilibrium solubility of hydrogen in iron carbon alloys; it was undertaken at the instance of the Joint Gases Sub-Committee of the Institute and the British Cast Iron Research Association. The experimental work is described and results are given of the equilibrium value for the solubility of hydrogen in alloys with carbon content up to 3·4%, over the temperature range 600–1,000° C., at pressures of one atmosphere. From these values it would seem that the solubility is of the same order over the range investigated; the values at 1,000° C. being around 5–7 parts per million. There is a minimum at 0·55% carbon, or thereabouts, and a maximum at 1·3–1·8% carbon, according to temperature. Grey irons seem to have higher solubilities than white irons of similar carbon content, the difference being of the order of 1–1½ parts per million.

B.S.I. Export Panel

The British Standards Institution announces the formation of a small Export Panel consisting of leading industrialists who are actively engaged in the markets of the world. The Panel will advise B.S.I. on how best it can assist export trade.

The volume and range of overseas work connected with standards has increased greatly in recent years, and has become a factor of growing importance to our exporting industries. The development of national standards in overseas countries has a direct bearing on British manufacturers' export activities, and therefore demands that British industry should, through the B.S.I., take a leading part in influencing developments in the international standards field. Fundamentally B.S.I.'s job in this sphere is to limit the necessity for British manufacturers to produce a variety of goods to comply with a variety of different standards in different countries. To enable manufacturers to take account of other countries' standards in their production for export, B.S.I. provides British industry with a complete service of information about overseas standards; and it is equally necessary that in formulating British Standards full account should be taken of the requirements of export markets as expressed in their own standards. The proper execution of this service to British industry calls for the best guidance which exporting industry can offer to B.S.I., and it is on these levels that the new Export Panel will operate. One practical task will be to suggest ways in which the use of British Standards overseas can be promoted, and how availability of British Standards in all parts of the world can be improved.

Formation of the new Export Panel has been actively helped by the Federation of British Industries, which at a recent export conference urged the need for further attention to these questions. The initial constitution of the new Panel is as follows: Mr. J. L. S. Steel (Imperial Chemical Industries, Ltd.), Chairman; Mr. G. H. Andrew (Under Secretary, Board of Trade); Mr. D. Maxwell Buist (British Electrical & Allied Manufacturers' Association); Mr. Leslie Gamage, M.C. (General Electric Co., Ltd.; President, Institute of Export); Sir Ernest Goodale, C.B.E., M.C. (Warner & Sons, Ltd.; President of the Silk & Rayon Users' Association); Mr. Hector McNeill (Babcock & Wilcox, Ltd.); Mr. J. W. Ridgeway (Edison Swan, Ltd.); and Mr. R. L. Wills, M.C. (National General Export Merchants' Group & London Chamber of Commerce).

Messrs. McNeill and Ridgeway were nominated by the F.B.I.

Crofts Acquire Tool Company

Crofts Engineers (Holdings), Ltd., of Thornbury, Bradford have acquired the whole of the share capital of J. Parkinson & Sons (Shipley), machine tool makers specialising in the production of milling machines; Sunderland gear cutting machines for either spur, spiral or double helical gears; gear testing machines for all types of gears. They also manufacture the well known "Parkinson" engineers vices. The present Directors Mr. Edward Parkinson and Mr. Harry Parkinson will still control the company under the existing management.

Pure Magnesium Price

Magnesium Elektron, Ltd., announce a reduction in the price of pure magnesium. Delivered customer's works, ingot will cost 2s. 3d./lb. for orders totalling 10 tons or more for delivery within one month, whilst the price of notched bar will be 2s. 7½d./lb. for orders totalling 10 cwt. or more with the same delivery period.

Aluminium Centenary Congress and Exhibition

St. Claire Deville's Discovery Commemorated in Paris

General view of the Exhibition building designed by Jean Prouvé.

THE aluminium industry of France—and indeed of the whole world—has received a timely fillip from the Centenary Congress which took place during mid-June in Paris, and the Exhibition which opened at the same time. The celebrations were held to mark the centenary of the discovery of the first commercial method for the production of aluminium, made by Henri St. Claire Deville in 1854.

It is opportune to recall that the existence of a metal in the oxide derived from alum had been postulated by Sir Humphrey Davy in 1807–1808, but although Davy attempted to extract the metal by electrolysis he was unsuccessful. To him, however, must be attributed its name, for he called the oxide " alumina " and the metal which he failed to extract " aluminum." (Incidentally, it was only later, as the result of international agreement, that the final " i " was inserted to give the less readily pronounced name of to-day, " aluminum." Although America adopted the new spelling, the pronunciation of the original word persisted to such an extent that " aluminum " became the accepted pronunciation in the New World, leaving the newer method of spelling to the Old World). The extraction of aluminium had to wait for nearly 20 years until the Danish chemist, Oersted, in 1825, reduced aluminium chloride with potassium amalgam. This was repeated in 1827, by Wohler, who also published a paper in which some of the properties of of the metal were described several years later. Little interest appears to have been taken in the metal until Henri St. Claire Deville, then aged 33, became head of the School of Chemistry in Paris in 1851. He persuaded the Emperor, Louis Napoleon, and the Academy of France to put up a sum of money to enable him to perfect his process for reducing aluminium chloride by metallic sodium. He managed to produce some small globules of aluminium which were exhibited and were the subject of papers presented at the Academy of Science in February and August, 1854. The process was adopted on a commercial scale without delay, and the metal was quickly used for decorative purposes, statuary and *objets d'art*. It was adopted abroad, particularly in Great Britain, and Deville's process held the field for more than 30 years, until the electrolytic reduction method was worked out by Paul Héroult in France and Charles Martin Hall in America.

The formal celebration of the Centenary took place at the Sorbonne on Wednesday, June 16th when Professor Georges Chaudron gave an address on " The Industrial Preparation of Aluminium and the Discovery of its Properties by an Illustrious French Scientist." This was followed by an allocution by M. Jean Matter, Director-General of l'Aluminium Français, entitled, " Industrial Consequences of the Scientific Work of Henri St. Claire Deville." A distinguished company heard these speeches, and at the Congress Dinner on the same evening further tributes were paid by Professor Albert Portevin, President of the Organising Committee of the Congress.

The Congress was the responsibility of the Société Chimique de France and l'Aluminium Français, the Secretariat being held jointly by M. Pierre Sue, Director of the Laboratory of the College of France and M. Robert Gadeau, Director of the Centre Technique de l'Aluminium. The Technical Sessions occupied two and a half days, and three simultaneous sessions were held, a total of over 70 papers being presented. There were two visits to works, to the Centre Technique and to less technical, but even more tiring, events at Les Chateaux de la Loire, the Opera and Versailles.

At the same time, Aluminium Français arranged a Centenary Exhibition intended to remain open until the end of July and possibly longer. This occupied the well-known Quai on the left bank of the Seine between Pont des Invalides and Pont d'Alma. Its appeal was to the general public and was exemplified by its slogan—" Aluminium, the metal that has given wings to progress."

THE CONGRESS

With three simultaneous sessions and with so many papers for discussion, it was impossible for any single individual, no matter how enthusiastic, to hear more than a proportion of the papers, and it is unfortunate that only about one-third had been pre-printed prior to the opening of the Congress. A system of simultaneous translation into French, English and German was of great assistance, and the ultimate publication of the papers and discussions should prove of outstanding value

The entrance to the Exhibition building.

to everyone concerned with the production or use of aluminium and its alloys. The present report therefore can act only as an appetiser for the forthcoming volume.

Extraction and Refining

At one of the first sessions, a particularly interesting review was given by Professor A. von Zeerleder on the development of electrolytic baths from the time of Héroult until the present day. He mentioned that Deville had produced small quantities of aluminium by electrolysis, as well as by his sodium process, but electric current was so expensive that the metal produced in this way could not be extensively used. The development of the modern reduction cell was divided by the author into three main time periods: first, 1886–1914, the initial commercial exploitation of the Hall-Héroult processes in practice; second, 1914–1925, the chief characteristic of which was the increase in the size of the cells and the use of pre-calcined electrodes; third, 1925–1954, great advances in the size of the cell and the development of the Soderberg type with increase in capacity up to 100,000 amps. This paper by one of the world's acknowledged experts, will undoubtedly rank as a classic in the history of the industry.

It was followed by an important contribution from Britain, namely a paper by Dr. P. Gross of Fulmer Research Institute on his subhalide distillation process for the production of pure aluminium. He gave details of the chemical equilibria involved, and then described the methods which have been used for measuring these reactions. The basic principles of the process were followed by a note that some of the reactions are of importance for the production of aluminium by other processes.

A paper by W. Syz, Director of the Chippis works, dealt with the development of super-purity aluminium. The principle of refining aluminium by electrolysis of three superimposed layers was discussed, and a summary given of the development of the design of cells. Following a section on the processing of high purity aluminium, information was given on the uses which have been developed, and data on polishing and anodic oxidation were included. Among the same group of papers was an interesting contribution by M. Van Lancker giving theoretical and experimental data on the electrometallurgy of aluminium, in which thermodynamic theory was applied to liquidus and solidus equilibria, the results being confirmed by X-ray diffraction work on crystals from the electrolyte.

Structure and Properties

From the many papers submitted on the microstructure and metallographic features of aluminium on a wide selection of alloys, several British papers may be noted. Thus, Liddiard and Hardy contributed from Fulmer Research Institute a useful summary of the aluminium-copper-cadmium alloys. The historical development of this series was first outlined, followed by data on the effects of variations in composition. The techniques of melting, casting, working and heat-treatment were then given, followed by information on corrosion and stress-corrosion behaviour. Typical properties were summarised and a number of specific applications suggested. Dr. D. E. Thomas of Aluminium Laboratories, Ltd., Banbury, reviewed existing information on the creep properties of aluminium alloys, with particular reference to the future use of aluminium at raised temperatures. He showed that there exists a great deal of information about the creep of the alloys specifically developed for service at elevated temperatures, but there are very few data on the long-term creep properties of the medium non-heat-treatable alloys of the aluminium-magnesium type. He suggested that the excellent corrosion resistance of this alloy series rendered them specially suitable for many applications in chemical engineering and other fields of application where temperatures are not excessively high, and where other materials are traditional. It was considered that the information available at present was inadequate to meet the demands which might be made by potential users requiring aluminium alloys for operation at moderately high temperatures. The author concluded his paper by a plea for more work on the creep characteristics of this group of alloys.

An American paper of interest was presented by T. L. Fritzlen, Chief Metallurgist of Reynolds Metals Co., on "The Unusual Coarsening of Grain in Some Aluminium Alloys." He first summarised information derived from a number of sources on grain growth of aluminium and its alloys, and went on to describe a number of specific problems which had been investigated on 99·5% aluminium, on the aluminium-1¼% manganese alloy, and on an Mg_2Si-type alloy. The author observed that from the practical point of view the alloys generally handled contain sufficient impurity to prevent grain growth from being troublesome, but investigations using the electron microscope showed the presence of sub-grains in the cast and wrought structures, and indicated that sub-grains may be a fundamental unit in the solid state, or may be formed due to strain set up during solidification. It was found that sub-grain size was not changed to any great extent by the treatments given to the materials in the investigations described.

Dr. P. Brenner and M. Schippers of Vereinigte Leichtmetallwerke, gave an account of microstructural changes occurring in the precipitation of homogenised aluminium-zinc-magnesium alloys produced from super-purity aluminium and containing up to 8·5% zinc and

The reception hall of the Exhibition building showing the form of roof construction. On the right is the historical section.

Models of the latest type of reduction cell forming part of the Exhibition.

3·75% magnesium. Samples were cast by the continuous process and were heated at 500° C., followed by slow cooling to study the decomposition of the solid solution. The occurrence of a fine network located at the grain boundaries and the formation of numerous intragranular veins was observed, together with precipitation of the concentrated phase at the original grain boundaries of the cast structure. These veins could not be observed after quenching followed by tempering at temperatures up to 350° C., and the precipitate occurred either mainly at the grain boundaries or within the grains according to the tempering conditions. Further information on this series of alloys would be welcome.

Two papers were discussed on sintered aluminium products, the first by Dr. J. Herenguel and the second by Dr. R. Irmann. Herenguel first stated the factors determining the characteristics of semi-products obtained from oxidised and sintered aluminium powder, among them being creep resistance up to 600° C. He stated these factors as: the condition of the basic powder; the conditions of sintering; and the deformation after sintering; and a study of them showed that a wide range of products could be obtained with gradually changing characteristics, thus enabling the conditions to be determined to obtain a product of the required properties. Irmann gave a summary of the properties and characteristics of powders used for making S.A.P. sintered products, together with static mechanical properties of the product at ordinary temperatures and at raised temperatures after prolonged heating. The creep strength and endurance limit were also discussed, together with a note on the oxide content and chemical properties.

Casting and Fabrication

At one of the sessions devoted to fabrication processes, the continuous casting of aluminium ingots for subsequent working and a study of the formation of ears during drawing proved particularly popular topics, five papers being devoted to them. The session opened with a review of those continuous-casting processes devoted to aluminium, submitted by Professor von Zeerleder on behalf of Dr. E. Herrmann. He gave a short historical review of the continuous-casting processes, and then a more detailed study of the three used industrially for aluminium at present, namely the Hunter-Douglas process, the Properzi process and the semi-continuous process with a fixed mould. The Properzi process was considered in more detail in a paper "Production of Aluminium Wire of Large Diameter on the Continuous Machine" by Lecis and Panebianco. The general principles of this type of casting and rolling machine were first set out and then a description was given of a series of studies undertaken to adapt the machine to the casting of large-diameter rods for electrical conductors. The paper included statistical results of electrical and mechanical properties of large-diameter wires and cold-drawn wires, in relation to the rolling conditions on this machine.

In a further paper, the relationship of the casting method to the production of ears in deep drawing provided the theme for G. Trapied. He stated that rolled material in aluminium and aluminium alloys cast by the continuous process possessed a grave disadvantage in producing in pure aluminium an anisotrophy which gave rise to the troublesome phenomenon of earing in subsequent drawing operations. He went on to claim that a new continuous casting process produced slower cooling than in the ordinary continuous processes and so enabled sheet to be produced without any tendency to earing. In this process water was sprayed on to the cool metal by air pressure in a controlled manner, the process being known by the name "Isomet." Continuous casting was also blamed by R. Chevigny as the cause of a distinct tendency to earing in the 90° position. He stated that homogeneization had an important influence on the formation of ears on material produced from continuously cast billets, and then proceeded to discuss modifications to the process intended to reduce earing.

Similar views were expressed by G. Siebel in his paper on the formation of ears, and superior results from chill moulds were claimed than from continuous casting. He also claimed that the rolling temperature had a very strong effect on the tendency to earing, and, in particular, that low rolling temperatures favoured the 0/90° position and high temperatures the 45° position of ears.

Earing formation during drawing operations was stated to be greatly reduced by cross rolling.

Corrosion and Protection

Corrosion and anodising formed the subject of a further session, when several papers were devoted to experience in Italy. Professor Panseri and Dr. Anna Gragnani gave the results of examinations of aluminium exposed to town atmospheres for long periods, and described chemical analyses, mechanical tests and micrographic examination of specimens removed from the aluminium roof coverings of two Roman churches, each dating back some 50 years. Although the purity of the metal was not high, the resistance to atmospheric attack was found to be good, and in the attacked areas corrosion took the form of pits less than 0·004 in. deep. The second paper by Dr. Anna Prati was on "The Galvanic Couple Aluminium-Graphite in the Corrosion of Light Alloys." A review of the literature on the corrosion of aluminium due to this couple was followed by a report of corrosion tests carried out on a super-purity aluminium, either insulated or short-circuited with a graphite electrode, and the results were plotted on potential-time and potential-current curves.

In a paper by P. A. Jacquet on the "Influence of the Surface State on the Corrosion of Aluminium," the author described experimental tests undertaken with various commercial grades of aluminium, both annealed and cold worked, exposed in different media. After a discussion of the results on specimens prepared in various ways, of which electrolytic polishing was stated to be the best, the author suggested that some of the results published in the literature required to be reconsidered, as the part played by the initial surface condition had not been taken into account to a sufficient extent.

Applications

One of the most interesting sessions was devoted to uses and applications of aluminium, and formed a fitting counterpart to the items shown in the Exhibition. The papers at this session and some of the papers at other sessions allowed certain comparisons to be made between British and foreign practice, and much useful information was given in some of the discussions.

Among the more general reviews was one by Dr. G. Perkins of the Reynolds Metals Co., in which he summarised the principal applications in the U.S.A. which had been brought to a reasonable degree of fruition in the past few years. He related usage to the properties of particular value, and divided his applications into several sections, including general sheet-metal work for building, such as ventilating ducts, curtain walls, awnings, venetian blinds, and windows, including fine wire insect screening. Hollowware, refrigeration equipment and furniture all account for considerable tonnages of aluminium in the U.S.A. The automotive industry is increasing its usage and the car and commercial truck were stated to use between 10 lb. and 70 lb. of aluminium per vehicle. In the case of buses it was considered essential to use aluminium up to as much as 25% of the total weight, whilst for trailers some 35–40% of the total weight would be in aluminium. The electrical industry accounted for some 10,000 tons for electric motors, and almost 100,000 tons for conductors. Comparative price figures for aluminium and copper showed that the cost of aluminium for the same current-carrying capacity was only one-third that of copper. Irrigation piping and fittings have made great progress in the U.S.A., and the paper concluded with a note on aluminium used in chemical work. Foil, powder and paste were also considered and estimates given for the sale of foil in the U.S.A. for several years, compared with tin and lead.

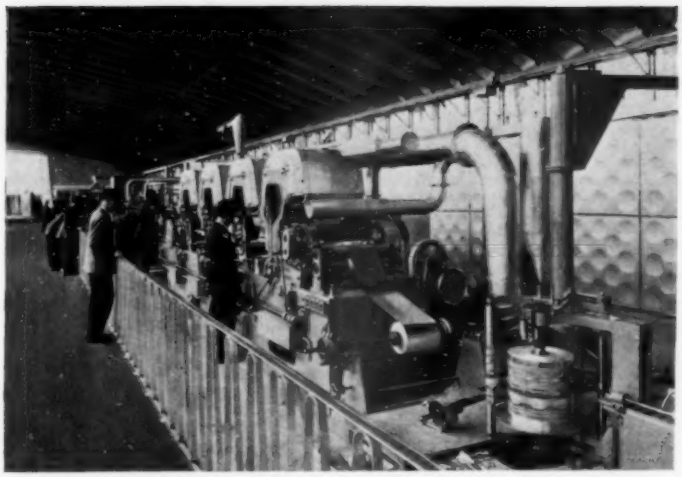
A review on a more limited field was made by Devereux, Pike and Smith of the Almin Group, in their paper on "Structural Applications of Aluminium." They outlined the principles which have led to the design of light alloy sections for the structure of many types of building, and illustrated the paper with typical examples, including the Dome of Discovery at the Festival of Britain, aircraft hangars, cinema roofs, warehouses, crane jibs and the well-known telescopic gangways. An especially important paper in the structural field was presented by Dr. K. Sutter of Aluminium Laboratories, Geneva, in which he made a strong case for a simplified formula for the calculation of failing loads for aluminium structural components. He referred to the series of buckling tests on struts carried out in Britain and Canada, and discussed the results in the light of the Perry-Robertson formula, the Euler and the tangent modulus curves. His paper formed a particularly valuable contribution, covering as it did the views of several important countries. A paper by R. de Fleury set out to give rules which would allow the transposition of materials and construction scales in the design of large structures, and this paper should also undoubtedly prove of interest to engineers in many fields.

A review of the uses of aluminium in architecture in Italy was given by Dr. Donatelli, and this was followed by a rather similar review by Struss devoted to aluminium in the Italian mercantile marine. It was stated that there had been a regular increase in the consumption of aluminium for shipbuilding from a maximum of 90 tons per ship before the war to as much as 200 tons in important post-war merchant ships. The Italians favoured the aluminium-

The 1,000-ton Loewy extrusion press with its induction heating furnace was engaged in producing sections and was a constant source of interest to the public.

magnesium type alloys, particularly containing 3·5% magnesium.

Two papers devoted to packaging attracted probably more attention than any others, the first being by Hugony of Italy, and the second by Lovell from Banbury. Hugony stated that aluminium was used to the extent of about 5,000 tons per annum in Italy, and considered that this could be greatly increased. A number of examples of foil and collapsible tube applications were given. Lovell set out to describe the developments undertaken at Banbury in collaboration with the Quick Freezing Research Association at Chipping Campden. He stressed particularly the technique developed for making shallow cans lacquered after drawing, and also cans drawn from pre-lacquered sheet. Tests were summarised following the canning of vegetables and fruit and their subsequent storage for periods of several years.



The Helio machine printing aluminium foil in four colours for packaging purposes.

W. T. Ennor of Aluminum Company of America showed an impressive film of the application of aluminium in the new 30-storey office building recently completed at Pittsburgh for ALCOA. The film shows in particular how the advantages of low weight greatly assisted the rapid erection of this building when used for wall panels, windows, air conditioning units, and partitions. The film, in colour, was a striking means of bringing this new development to the attention of the audience, and it was learned that several other buildings, some of them even larger than the ALCOA block had been erected in still shorter times. This film was shown immediately after a much more modest sound film which had its premiere at this meeting, namely the building of the Aberdeen bascule bridge in 90 days—a film made jointly by the builders, Messrs. Head Wrightson Ltd., and the Aluminium Development Association. These films aroused considerable interest.

THE EXHIBITION

The Exhibition by l'Aluminium Français was on one of the finest sites in Paris, and occupied a total length of quay exceeding 500 yd. The central feature was a building, specially designed by Jean Prouvé, more than 450 ft. long by about 45 ft. wide, plus an extensive space between the building and Pont d'Alma where many examples of large-scale usage were shown. A pleasant restaurant and bar had been erected of aluminium pre-fabricated units and furnished with contemporary light alloy furniture. The Exhibition had been provided as a means of bringing to the attention of the public the progress made by aluminium in its first 100 years of commercial history, and there was no doubt about the interest aroused.

The building itself was very striking with its façade over 20 ft. high facing the river. It was constructed of slender aluminium alloy struts, some 4 ft. apart, between which were large panes of glass or metal panels with suitably textured surfaces, the panels and glass being readily interchangeable as they were held in place by a system of clips. The roof of the building was especially striking, and the inside appeared æsthetically pleasing as it was entirely free from the usual roof trusses and purlins associated with exhibition buildings of this size. Some of its features are shown in the accompanying illustrations.

As will be seen from the photograph, the roof sloped from the river façade to the back wall, and the structure was of a new form. Each section consisted essentially of three channels of troughed sheeting to form the segment of an arc, and the channels so formed acted as girders. The three troughs were connected by bolting to castings of thin section, and the space between troughs was covered by sheet turned over into the open trough. The troughs and the sheeting thus comprised a unique form of self-supported corrugated roof, spanning the full width of the building and giving an uninterrupted interior. The building was erected in five days, with very few men, and the units were of such a size as could be readily handled with very light equipment.

The sections were extruded from the 3½% magnesium alloy (equivalent to the British N.5 alloy of B.S. 1476), the roof sheets were of the same composition (NS.5), and the cast connecting pieces were of a nominal 4% silicon alloy. The building was braced with steel wires at the rear, and the pillars on this face were hollow for the conveyance of rainwater from the troughs.

The entrance hall of the building included a number of historical exhibits of early uses of aluminium, and illustrations showing the pioneer work of the first 40 years. Beyond this there was a model of the latest type of Soderberg electrolytic reduction cell with well illustrated captions. This was followed by the section which included working equipment on production jobs. There was first a large cold-chamber pressure die-casting machine, followed by a 1,000-ton Loewy extrusion press with an induction furnace for billet heating. Next was a 27 in. wide foil-rolling mill, followed by a foil-printing machine engaged on four-colour work. In this section there was also an impact extrusion press of 250 tons capacity producing 60 or 70 1-in. diameter tubes per minute. All these machines aroused great interest among the public visiting the Exhibition.

The next section was devoted to welding processes; which included a large spot welding machine and a flash welder for window frames. The argon arc process was demonstrated periodically. The final section of this part of the Exhibition was a complete anodic oxidation plant with electrolytic polishing, dyeing and sealing in a continuous plant.

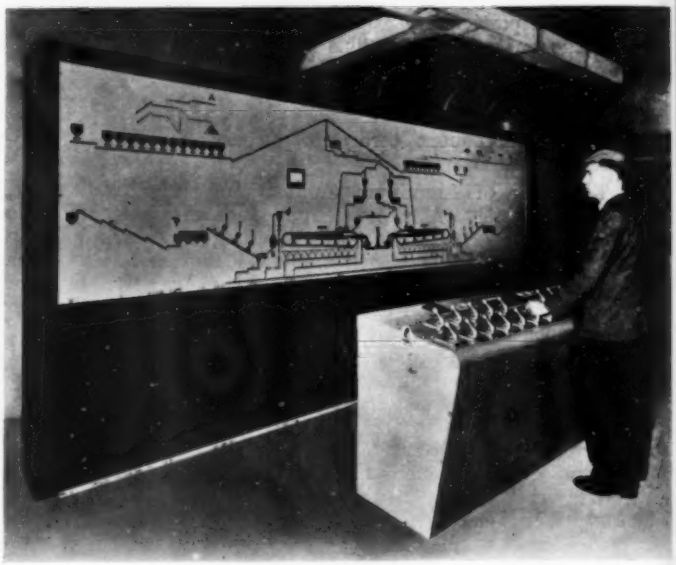
A particularly popular resting place in the Exhibition

was the cinema, in which were shown a selection of films made in France on various aspects of aluminium. The final section of the Exhibition within the building was devoted to examples of the use of aluminium alloys according to the properties which made them suitable and economic. Outside the building, on the quayside, were a number of very interesting large exhibits showing actual applications, of which the most comprehensive showed the use of aluminium in the electrical industry. These items ranged from overhead conductors to busbars and low-voltage wiring, as well as many examples of equipment. The body of a Panhard-Dyna saloon car was suspended from a spring balance to show its low weight, and there were also two railway vehicles—a diesel rail car embodying many aluminium fittings, and a very large alumina wagon. A number of boats were exhibited, as well as a mine car and cage. Building applications were shown by an impressive display of windows, various forms of roof covering and several types of pre-fabricated unit. Altogether the Exhibition formed an impressive illustration of the progress made in the application of aluminium in France.

Material Handling Indication Diagrams

AN interesting example of the industrial application of electrical indication diagrams is provided by Standard Telephones and Cables, Ltd., in a new approach to the problem of indicating the condition of widely dispersed raw material processing and handling machinery at the Margam plant of the Steel Company of Wales. "Standard" electrical indication diagrams of a new design are now enabling operators at the recently commissioned Margam ore preparation plant satisfactorily to monitor machinery used in the production of rubble, iron ore, coke breeze and sinter.

All raw material at the plant is completely machine-handled by power-operated conveyors and gravity chutes. Three plant layout electrical mimic diagrams are provided, one each for the ore crushing and screening plant, coke breeze preparation plant, and the sinter plant, each showing a miniature diagrammatic layout of the plant, the condition of every conveyor motor, oil pump, screen, crusher and chute. Installed adjacent to the plant controllers, the diagrams indicate the settings of material flow path selection switches by means of red and green lamps. A red lamp indicates a selected machine which is not yet moving, and a green lamp signifies moving machinery and a static gravity chute. As the individual starting contactors are closed, the appropriate red lamps on the mimic diagram change from red to green. The particular route for the material is then clearly indicated by a series of green lamps, together with the symbols inset on the diagram. By this means the plant operator can check, before engaging motors, the path which the material will take, and that all necessary motors have been started. Whilst the process is running the route of the material is shown on the diagram, and the failure of any motor can be located immediately by reference to the diagram.



Sinter plant indication diagram.

Special precautions have been taken to ensure that the mimic diagrams are unaffected by dusty and dirty site conditions. Arrangements have also been made for easy cleaning and maintenance. The diagrams are constructed of a hard durable plastic, and the coloured symbols, lines and lettering are permanently bonded into the plastic during the manufacturing process. They are mounted in steel cubicles with rear access doors closing against rubber facings. The lamps on the diagrams are operated by telephone-type relays mounted in glass-covered apparatus units contained in steel cubicles and housed in a pressurised room. Using telephone technique the cabling between apparatus cubicles and diagrams is carried out in 20 lb./mile multicore cable, and the system is operated at 50 volts D.C.

The introduction of electrical indication diagrams of this nature should greatly assist the rapid readjustments of plant in the event of stoppage, and the issue of instructions for setting up alternative paths. The layouts of these diagrams were evolved by the Consulting Engineers, Messrs. McLellan & Partners, in conjunction with the Steel Company of Wales, and the equipment was designed and manufactured by Standard Telephones and Cables Limited within twelve months of receipt of the order.

Hungary's Aluminium Yachts

THE prototype of Hungary's first aluminium 50-sq. m. type sailing boat has been made at the Balatonfured shipyard, and will have its trials in the next few days on Lake Balaton states a report in the Hungarian Press. Next month work will be begun on a larger boat, fitted with a motor. Work has also begun on a luxury seagoing motor cruiser, 59 ft. long with a 15 ft. beam, due to be launched in October.

Non-Destructive Testing Discussed

Institute of Physics Conference in Birmingham

By a Special Contributor

The rapid progress made during the war in the science of non-destructive testing continues and the former Industrial Radiology Group of the Institute of Physics has been renamed to indicate its widened scope. At the Summer Meeting of the Group, held recently in Birmingham, a brief account of which is presented here, papers on radiography, electrical and magnetic methods, and ultrasonics were discussed.

THE 1954 Summer Meeting of the Non-Destructive Testing Group of the Institute of Physics was held in Birmingham between July 7th and July 10th. This Group of the Society was formerly the Industrial Radiology Group and has been retitled in order to recognise more adequately the activities of its members. The meeting was opened by Mr. W. E. Schall, the Group Chairman, who welcomed the delegates and expressed their gratitude for the work put in by officers and local society members in the organisation of the meeting. Over 70 individuals were in residence and attendance at lectures rose to 160 or more.

Professor Murphy of Birmingham University set the stage for the meeting in an after-dinner address the first evening, when he gave an interesting talk on the place of the group and its activities in industry. He made particular reference to the fact that, while the radiographer should be a physicist, the radiologist, whose duties are the interpretation of and adjudication upon the radiographs, should be a metallurgist. There were occasions when the rejection rate after radiography became unduly high, so that the radiologist, instead of determining which were the few parts meriting rejection, was compelled to search for those good enough to pass. When such a situation arose, Professor Murphy contended that the manufacturing process was out of control, and radiology no longer adequate to ensure the satisfactory standard even of those parts which were passed. He suggested there was a critical rejection rate for a given process. Professor Murphy also put in a plea for more consideration of the economic aspect of non-destructive testing, a problem which was frequently referred to during the rest of the meeting.

Eight papers dealing with radiology, electrical and magnetic methods of non-destructive testing and ultrasonic techniques were presented for discussion and a brief outline of them is presented below.

RADIOLOGY

THE SENSITIVITY OF RADIOGRAPHIC TECHNIQUES WITH ISOTOPES

R. HALMSHAW, B.Sc., A.Inst.P.

In dealing with the problem of securing the highest sensitivity of radiological methods, i.e., high contrast and good definition, it was necessary to determine what factors were most significant. With reference to penetrameters, Mr. Halmshaw expressed a preference for the step type, although there was a good case for the use of the wire type on occasion, but neither of these was necessarily closely related to the working sensitivity.

The minimum discernible difference on test radiographs was considerably dependent on the type of viewing lantern used, and in his opinion the best results were given by working at a high film density, the desirable opacity rising to a density of 6 to 8. Mr. Halmshaw had a good deal to say about viewing conditions, and he considered 1,000 candles/sq. ft. a desirable minimum for the viewing screen, with every precaution to reduce scattered illumination of the film.

The lecturer dealt with the use of screens and showed graphs illustrating the relation between scattered and direct radiation on the film during exposure. These were plotted experimentally for carefully-controlled conditions, and a special lead collimator was used for the determination of the effect of direct radiation. He showed sensitivity curves for Thulium 170, Iridium 192, Caesium 137, Cobalt 60, radon, and 200 kV and 400 kV X-ray radiations, and gave preferred steel thicknesses as 0·2–1·2 in., 0·7–3·0 in., 1·0–3·5 in., 1·5–7·0 in. and 1·2–8·0 in. respectively. In his opinion, for steel plate up to 1 in. thickness, 200 kV X-rays were better than higher energy X-rays or any isotope; for 2 in. steel thickness 200 kV X-rays were still suitable but 400 kV or isotopes were equally suitable; for 3 in. steel thickness 400 kV to 1 MV X-rays were equal, while over 3 in. steel thickness required 2–10 MV X-rays.

Mr. Halmshaw showed that when it was possible to use the penetrameter at least $\frac{1}{4}$ in. of metal away from the film, accurate results were obtained irrespective of metal thickness, but that when this was impossible a reasonable approximation might be made with the penetrameter next to the film. Where penetrameter sensitivities were given in specifications, it was necessary to state what type of penetrameter was to be used.

INTENSIFICATION OF THE X-RAY IMAGE

A. NEMET, Dr.Ing., F.Inst.P., and W. F. COX, B.Sc.

This paper was presented by Dr. Nemet, and was devoted to the new technique of image intensifier tubes applied to fluoroscropy. The lecturer gave details of the improvements already made on normal fluoroscropy in medical radiology, and indicated the various stages at which amplification was possible. Briefly, the apparatus shown consisted of a fluorescent screen mounted on aluminium foil with a coating of photo-emissive material, the multiplied electrons from which were accelerated and focussed on to a small fluorescent screen which was observed with an eyepiece, or photographed on 35 mm.film.

A net gain in brightness of 1,000 times could be secured in favourable circumstances, although even so the sensitivity obtained was not equal to that attained by radiography, owing to additional sources of poor definition in the image intensifier. Advantages of the new process over normal fluoroscopy included the improvement in visual acuity due to the increased brightness and

the consequent shift from cone to rod vision, and the reduced dark adaptation time.

It was also important to note that the size of the radiation source controlled the amplification possible without undue focal and screen blurring ; some help was given here by the fact that lower voltages could be used, due to the improved conditions of viewing. Dr. Nemet dealt at some length with the way in which the statistical variation, due to the discrete nature of radiation, placed a lower limit on the intensity of radiation which could be used.

According to Dr. Nemet there was reason to suppose that the results in industrial work would be between those obtainable now with contact radiography and fluoroscopy, but nearer to the former when direct viewing of the final image was used, and significantly improved if photography was used instead. A marked gain in storage space was possible if 35 mm. film was used, together with a considerable reduction in film cost.

SOME EXPERIMENTS ON DIFFRACTION MOTTLING

J. R. Rait, D.Sc., A.R.T.C., F.I.M., and H. S. Peiser, M.A., F.Inst.P.

The paper was introduced by a short historical note by Dr. W. Betteridge, in which he surveyed briefly the incidence of the problem in so far as it affected industrial radiology. The paper itself was presented by Mr. H. S. Peiser, who remarked that the problem had become more severe recently, since large grain sizes were now often desired by engineers, especially for high temperature alloys, and the effect was intensified under these conditions. Precision castings of very creep resistant alloys showed the effect to a marked extent. The lecturer showed how the phenomenon arose, and how it was intensified as the grain size increased, and indicated the place in the phenomenon occupied by the effects of polarisation, the Lorentz factor, and the effect of temperature. He also stressed that the better the quality of the radiograph the more noticeable the effect. The paper was illustrated by slides of the special apparatus used by the authors to produce and measure the effects.

With regard to a cure, Mr. Peiser stated that the possibility of restricting the effect to one wave length by ensuring that the material was completely strain-free was not a practical solution. At the same time, since the actual mottle pattern changed significantly for a movement of the specimen of 20 minutes of arc, defect indications which remained when the specimen was turned over were true, and indications which changed were due to diffraction mottle. A further point made was that the amount of mottle increased with increasing distance between specimen and film.

FORUM

The lecture on diffraction mottling was followed by a Forum whose panel members were :

Mr. A. H. Goodger (National Boiler and General Insurance Co., Ltd.).

Mr. S. H. Griffiths (John Thompson & Co., Ltd., Wolverhampton).

Dr. R. F. Hanstock (High Duty Alloys, Ltd.).

Mr. G. T. Harris (Wm. Jessop & Sons, Ltd.).

Dr. H. Harris (Babcock and Wilcox Ltd., Renfrew).

The questions dealt with included the following :

What are the most generally useful non-destructive tests for product inspection and control? Which tests does the Forum consider to be more specifically useful in research or in process development ?

What essential requirements are, in the opinion of the Forum, not met by current methods of testing ?

Can differing methods be economically co-ordinated for inspection purposes or do they lead to confusion ? Would the Forum give examples ?

What are the views of the Forum on X-ray and gamma-ray safety precautions ? Do we need more legislation, or less—or a new approach ?

Does the Forum consider that producers are adequately consulted in the preparation of standards of acceptance with which they are expected to comply ?

How near are we to a simple and adequate test for examining the whole cross section of butt welds ? (Solid phase pressure butts or flash-welded butts).

An interested discussion followed, to which members of the panel and the audience contributed.

ELECTRICAL AND MAGNETIC METHODS

THEORY AND APPLICATION OF ELECTRICAL AND MAGNETIC METHODS OF NON-DESTRUCTIVE TESTING

(i) R. H. Wallace, A.M.I.Mech.E.

In the first of the three papers, Mr. Wallace dealt with the practical use of direct and indirect magnetic methods and direct electrical methods. The subject was divided into three main parts. The first part dealt with the principles and application of magnetic crack detection, and the lecturer made the point that direct magnetic methods were almost entirely confined to the detection of defects, and were rarely used for sorting. Application was confined to ferrous parts.

With respect to the use of magnetic sorting, on which Mr. Wallace spoke at some length, this technique was also shown to be confined, in the main, as far as application of the more normal type of sorting bridge was concerned, to parts made of steel of various sorts. The lecturer dealt with the effects of the different variables concerned in producing magnetic differences which were reflected in the indications of a sorting bridge, and showed how the effects of composition, structure and heat treatment, dimensions and state of stress of the parts were inter-related. He expressed a strong preference for the use of a cathode ray tube indicator, and gave an indication of the respective limits of galvanometer and CRO indications in regard to actual use. It was shown that the effects of the different factors involved in sorting could be more easily distinguished with a CRO indicator, and slides were shown illustrating the effects of these variables on the CRO trace of specific steel parts.

Reference was made to the use of magnetic sorting on non-ferrous components, and the lecturer stated that, while a certain amount of this sorting could be done, there were other methods better adapted to this purpose. The scope of magnetic sorting within an organisation was indicated, and the considerable improvement in control made possible was stressed.

In dealing with the use of resistance testing methods, Mr. Wallace dealt with the fundamental principles, and

with the reasons which lay behind the use of a four-electrode arrangement in obtaining accurate results with metallic specimens. He showed that the effects of composition were paramount in resistance sorting, and that state and other factors were secondary. In this connection, it was pointed out that since these other factors were considerably reduced in their effect, it was possible to undertake types of sorting which were difficult by sorting bridge methods. The effects of solute atoms in metals on conductivity were shown to be considerable, and the lecturer referred to the profound effects of arsenic, tin and phosphorus in copper, and of silicon in magnetic steels.

In conclusion, Mr. Wallace stressed the importance of electrical and magnetic methods, in particular magnetic sorting, in enhancing the value of destructive tests. He pointed out that if, before the selection of percentage destruction tests, the uniformity of the batch was checked by indirect methods, then the probability that all the batch was correctly represented by the test sample was greatly enhanced. This factor alone could make indirect methods a very valuable adjunct to routine testing.

THEORY AND APPLICATION OF ELECTRICAL AND MAGNETIC METHODS OF NON-DESTRUCTIVE TESTING

(ii) E. G. Stanford, M.Sc., Ph.D., A.Inst. P., and H. W. Taylor, B.Sc., A.Inst.P.

Dr. Stanford introduced the paper and gave a short illustrative note on the work which had been done on this subject at his firm. He indicated that during the war the use of eddy current testing to monitor the quality of the output of aluminium alloys had been considered, and for the time being shelved as of lesser value than other methods, particularly ultrasonic ones. Following Dr. Furster's work, the matter had been re-examined and a good deal of work was now being done to determine how far the method could be of value in their field. The factors chiefly affecting the resistivity of the material were composition and heat treatment, the latter particularly important in the case of precipitation hardening alloys.

Dr. Stanford indicated the mathematical factors involved, the method of dealing with the calculations using Bezzel functions for bars in coils, and the calculations for a coil applied to the surface of a sheet, which he dealt with by Maxwell's method of images. He showed that under suitable conditions the effects of dimensional variation and resistance variation could be arranged so as to affect the coil in quadrature, and in these circumstances it was relatively easy to separate these quantities electronically and display them in a suitable manner on a cathode ray tube, or as meter indications.

Mr. Taylor then spoke on the practical experiments carried out to determine to what extent the methods could be applied to product control. He pointed out that the method was, for the time being at least, restricted to relatively simple geometrical shapes, and to bar of uniform cross section, or sheet of uniform thickness. The salient feature which they had found in their experiments was that the greatest importance must be attached to the maintaining of satisfactory dimensional relations between the coil and the work ; the frequencies which they had found to be preferable were between 200 c/sec. and 10 kc./sec. Changes in resistivity such as would be secured by the effects of composition changes and/or precipitation hardening produced quite small changes in quadrature compared with the larger changes due to dimensions or movement of the coil in respect to the work.

The speaker then dealt with the separation of the two components arising from the change in dimensions and resistance, firstly by the use of a CRO (in which case he preferred to use a circular time base) and showed slides indicating how these changes affected the trace. Electronic amplifiers of the phase sensitive type could also, he said, be used so as to present the resistance and dimensional variations on separate meters.

With regard to the frequency used for testing, the lecturer stated that 15 kc./sec. could be satisfactorily used on material of 0·050 in. thickness and the resistivity could, under favourable conditions, be read to an accuracy of 1–2%. Thickness testing of tubes could be carried out quite satisfactorily, provided that choice of the optimum frequency was made, while the resistance component could give information on uniformity of composition.

With regard to flaw detection by this means, Mr. Taylor stated that the choice of frequency was of paramount importance, since anomalies were evident at certain critical frequencies. Frequencies of about 10–20 kc./sec. were satisfactory for many of the normal applications.

THEORY AND APPLICATION OF ELECTRICAL AND MAGNETIC METHODS OF NON-DESTRUCTIVE TESTING

(iii) L. T. Perriam, B.A., A.Inst.P.

Mr. Perriam, in his paper, covered the more practical applications of the theoretical methods indicated in the previous paper with respect to tubes; in particular, testing of tubes in condensers, testing of tubes at high speeds, and the constructional features of apparatus for these purposes. He indicated in his introduction how necessary it had become to find a means of examining the whole length of the tubes in a steam condenser or heat exchanger, not only as they were manufactured, but also during service. In order to accommodate the high speed of tests required, such measurements were perforce made by electronic means.

He showed the structural details of probes constructed in order to carry out these tests and referred briefly to the theoretical considerations of the coil-work relationship. Bridge circuits were used, and the frequencies adopted were of the order of 1,000–5,000 c./sec. It was normal to filter the output of the bridge and discard harmonics before amplifying the indications required.

With regard to the materials of the probes, Mr. Perriam stated that there was reason to hope that ferrites would be more satisfactory than the present soft iron. Considerable attention had to be given to the construction of these pick-up devices to render them robust and accurate. In the works testing of tube at the moment it was more usual to use coils around the tube as they were more conveniently applied, but it was indicated that it might be necessary to use a pick-up working inside the tube to achieve the best sensitivity. Two coils were normally used in the probe, adjacent to each other so as to neutralise changes due to temperature variations and to compensate for any resistivity variations from tube to tube. The only type of defect which, under these circumstances, would escape detection was that where a guide mark or lap occurred throughout the entire length of the tube.

Rates of 2½ ft./sec. were readily obtained, and 6 ft./sec. was quite possible with suitable modifications to the mechanical parts of the system. It was possible to separate to some extent, the effects of thinning of the tube wall from the effects of defects.

Mr. Perriam then dealt with the sorting of mixed material by certain special electrical methods. He indicated the manner in which the tribo-electric effect, which is, of course, due to the frictional e.m.f. obtained on rubbing two dissimilar metals together, could be used to effect sorting of different materials, or of batches of different composition within the same material group. The advantage of this method was that it was independent of shape and size of the component. It was, however, considerably dependent on the surface texture and cleanliness. He indicated some particular cases where very successful sorting had been done.

In conclusion, the lecturer dealt with the sorting of various types of bar and tube samples in a single coil by eddy current effects, and showed that satisfactory sorting could be maintained as long as there was less than 0·1% of iron present in the material, and also referred to the value of the potential drop method where iron contents were higher.

ULTRASONIC TESTING

THE PROPOGATION OF ELASTIC WAVES IN SOLIDS

H. Kolsky, Ph.D., F.Inst.P.

Dr. Kolsky dealt, in his paper, with the different types of elastic wave which could be propagated in solid materials, and indicated their relation in regard to energy and reflection. The theoretical basis for the reflection of transverse and dilatation waves and their velocity relationships was also discussed.

Tests made with Perspex using high speed photography with polarised light and also with rods of glass, showed the wave conditions obtaining, and Dr. Kolsky went on to show how they had arrived at the use of a fine filament or wire of material to give consistent results, and to eliminate the various sources of error present unless an infinitely large block of material was used.

The lecturer showed how the damping could be measured and indicated the various physical processes from which it arose. The measure of damping was a useful method of determining the grain size, and he was making considerable use of it for this purpose. Work done by his organisation had tended to centre largely on the use of organic glasses such as glycerol sextol phthalate.

Dr. Kolsky also dealt with the subject of ultrasonic pulses in thickness measurement, and extended his observations on the transmission of these waves to the more practical cases encountered in thickness measurement and in flaw detection.

THE ULTRASONIC TESTING OF WELDS

J. D. Hislop, M.A., A.Inst.P.

Mr. Hislop, in his opening remarks, compared the efficiency of radiographic and ultrasonic testing as applied to welded seams, and gave his assessment of their relative value. He contended that greater use could be made of ultrasonics so as to reduce the amount of radiography which was necessary. He dealt with the necessity to arrange matters so that, as far as possible, the operator had satisfactory working conditions, and illustrated with slides the circumstances in which a good deal of their work had already been done—for example, the testing of welded pipe situated high up in the structure of a power station, or the testing of welds in a tube inside which the operator had barely room to move. The lecturer stated that the conditions for ultrasonic testing butt welds were relatively easy, while the examination of fillet welds was very difficult, although this latter could sometimes be dealt with from the back surface in regard to some of the defects likely.

He showed by slide how the ultrasonic transducers could be applied in the testing of welds, and gave details of the application of these, singly and in pairs, and in certain cases the use of two on one side of the weld for the accurate determination of the position and extent of defects found. He illustrated a special type of slide rule which had been developed, and gave in great detail the application of the method to butt welded joints. In his opinion, the application of the method was much more satisfactory with Class I welds where almost any defect was objectional, than in the case of Class II welds, where defects of the same size but of different nature had to be distinguished. Mr. Hislop did not claim that the method was any substitute for radiography, but he did claim that it was a very valuable adjunct, and would save the radiography of a very large proportion of the welds, those suspect being the only ones examined in that way. Automatic scanning was difficult, but for certain types of weld produced in large footages was quite a possibility.

In the discussion which followed, it was evident that few of the members appeared to be happy about the substitution of ultrasonic for radiographical examination, the general feeling being that failure to observe serious defects might well be involved in the use of ultrasonic examination alone.

Canning Sheffield Move

After 31 years at the Sycamore Street address, the Sheffield branch of W Canning & Co , Ltd., has moved to No. 1, South Parade, Shalesmoor. The new premises, which occupy an important island site near the city centre, have undergone extensive structural alterations in order to accommodate large stocks of equipment and materials necessary to meet increasing requirements of the plating trade in the North.

In addition to offices, warehouses and loading bay, the building includes a retail shop and showroom. An analytical laboratory will, in due course, be available. This will be of particular interest to Northern plating houses which do not have their own laboratory facilities and will enable them to have solutions speedily and accurately analysed without the possibility of delays caused by transport difficulties. Canning transport, operating from the new premises, will cover Sheffield and the West Riding areas with greatly improved delivery service.

Change of Address

International Meehanite Metal Co., Ltd., have moved to new office premises at Meerion House, 4 Downside, Epsom, Surrey (Tel.: Epsom 3507/8). Meerion House is five minutes' walk from Epsom main line station.

Creep and Fracture of Metals at High Temperatures

Symposium at the National Physical Laboratory

(*Communicated to* METALLURGIA *by E. I. Brimelow, M.Eng., A.I.M., Assoc.I.Mech.E., Industrial and Scientific Liaison Officer, N.P.L.*)

Workers from many countries met at the National Physical Laboratory recently to discuss fundamental problems concerning the strength of metals at high temperatures in the light of present knowledge. One outcome of the Symposium was a realisation that a better understanding of creep processes is being achieved as a result of both theoretical and experimental approaches, although much remains to be done before creep-resisting alloys can be designed.

A SYMPOSIUM on the Creep and Fracture of Metals at High Temperatures, a subject of considerable practical importance and theoretical interest, was held at the National Physical Laboratory, Teddington, from 31st May to 2nd June, 1954. It was attended by eminent scientists, metallurgists and engineers from many countries, including Belgium, France, Germany, Holland, Italy, Japan, Norway, Sweden, Switzerland, U.S.A. and U.S.S.R., as well as from the Commonwealth countries and the United Kingdom. The visitors were welcomed by Sir Edward Bullard, the Director of the N.P.L., who took the Chair at the Opening Session.

The Symposium provided an excellent opportunity for workers interested in fundamental problems concerning the strength of metals and alloys at high temperatures to get together to discuss new ideas that had arisen concerning plastic deformation and fracture since the last short conference on Creep in Metals arranged by the N.P.L. in 1946. The papers presented, and a record of the discussion, will later be published *in extenso* as "Proceedings" of the Symposium, by H.M. Stationery Office. In the interim, this synopsis is intended to outline some features that may be of immediate interest to those concerned with the application and development of high temperature metals.

Practical Implications of Creep Phenomena

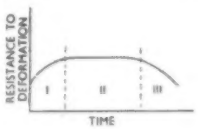
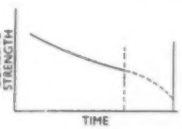
In his introductory paper,[1] DR. N. P. ALLEN, Superintendent of the Metallurgy Division, referred to present-day problems in the development and use of creep-resisting alloys. In particular, he stressed the need for more information on the creep behaviour over very long periods of special heat-resisting steels originally developed for use in aircraft gas turbines on the basis of a comparatively short life of 300 hours, or less. Today there is a considerable interest in power units having a much longer life, up to 100,000 hours, for commercial aircraft, marine and land power units. Extensive series of creep tests made at the N.P.L. for periods of 10,000 hours, or more, had confirmed the sound practice of lowering the working temperature of a gas turbine engine as the expected life is increased. On the other hand, if a high thermal efficiency is required some sacrifice of working life may be necessary. As an example of the difficulties of predicting the behaviour of certain steels in service from the results of creep tests under very different conditions as regards duration and stress, reference was made to the cracking of ½% molybdenum steel steam pipes which occurred in a power station. These pipes failed in an unusually short time, although the long-term creep test results at moderate stresses were satisfactory. It was subsequently shown that the failures were due to high short-lived stresses set up at points of stress concentration by thermal stresses arising from irregular operations under war-time conditions. This example, as Dr. Allen stated, showed the complexity of questions of fracture, and the need for understanding the behaviour over a wide range of creep conditions.

A question of practical importance to the designer of large power units is the effect of size of component on creep properties, that is, whether large components made in a particular steel can be expected to have creep properties at least equal to those shown by small test pieces. A few creep tests were, therefore, made at the N.P.L. on an austenitic steel disc 18 in. dia. × 4½ in. thick, and a ⅝ in. dia. bar of the same composition, also on steam pipes 13 in. dia. × 2 in. thick and superheater tubes 1¾ in. dia. × $\frac{3}{16}$ in. thick made in a ferritic ½% molybdenum steel, and a similar comparison was made between pipes and tubes in an austenitic steel. The results were reassuring in that, although the shape of the creep curve is affected by different manufacturing processes associated with the size and form of the component, average creep rates taking into account directional effects in the large components, were not appreciably different.

The tendency to increase working temperatures in both steam and gas turbines has posed new problems. This trend to raise steam temperatures to 600° C., and probably 650° C., from the former maximum of 550° C., has raised economic problems as to the temperature at which a ferritic type steel, such as the 0·5% molybdenum 0·25% vanadium steel, should be replaced by more costly austenitic type steels, such as the 18% chromium, 12% nickel, 1% niobium steel, which are certainly superior above 650° C., but offer no advantage at temperatures below 550° C. Creep tests on the ferritic steel at 626° C. and on the austenitic steel at 635° C. had shown the austenitic steel to be much superior in creep resistance at stresses of the magnitude of those met with in superheater devices and steam pipes. It was questions of this kind, Dr. Allen pointed out, that emphasised the importance of knowing the origin of the increase of creep rate that occurred in the third stage of creep.

Of considerable practical importance is the study of the fracture of metals under complex creep stress conditions. Most of the information available concerning the

TABLE I.—INFLUENCE OF VARIOUS FACTORS ON TRANSCRYSTALLINE FLOW AND THE DEVELOPMENT OF INTERCRYSTALLINE CRACKS. (AFTER Dr. SIEGFRIED[3])

Factor	Transcrystalline flow	Development of intercrystalline cracks
Stress conditions	Peak stresses are reduced	No reduction of the peak stresses. (A new peak always present at the end of the crack)
Type of fracture	Fracture as a result of neck formation	Brittle fracture
Material	Reduction by : 1. High recrystallisation temperature 2. Precipitation	Reduction by high recrystallisation temperature. No reduction by precipitation processes
Dependence on time		
Cold working	Reduction	1. Unchanged in stable alloys 2. Increased in unstable alloys
Sigma phase formation	Reduction	Increase

creep properties of metals and alloys is based on tests under simple tensile or compressive stresses, although it is well known that fractures in service have frequently occurred under more complex stress conditions. From this point of view the paper[2] by Dr. A. E. Johnson and Mr. N. E. Frost (Mechanical Engineering Research Laboratory) was a most useful contribution. This work showed that for a 0·5% molybdenum steel at 550° C. the time of fracture and nature of the fracture depended on the stress system, e.g., under a simple tensile stress of 9 tons/sq. in., intercrystalline fracture occurred after 684 hours, and under a pure torsion stress of 6·5 tons/sq. in., a transcrystalline fracture occurred after 1,403 hours. With a combined stress system of 9 tons/sq. in. tension and 5 tons/sq. in. torsion, fracture occurred after 234 hours, and was partly intercrystalline and partly transcrystalline. The results so far obtained in this investigation of the effect of complex stress systems led to the tentative conclusion that the criterion of fracture may be the maximum principal (tensile) stress of the system imposed.

The rapid development of fractures in such components as bolts and blade-root attachments, that is, those of a type embodying structural notches, even when made in heat-resisting steels, has led to investigations into the development of intercrystalline fractures in various steels under tri-axial stress conditions such as are set up when notched specimens are stressed. The results of creep tests on a wide range of metals under these conditions formed the subject of an interesting paper[3] by Dr. W. Siegfried (Sulzer Brothers Ltd. (Switzerland)). He found that there were three ways in which cracks may develop in cold worked specimens : (*a*) intercrystalline cracks running transverse to the direction of pull and beginning at some distance from the root of the notch ; (*b*) partly crystalline and partly intercrystalline cracks at the root of the notch itself, not penetrating far into the interior ; and (*c*) haphazardly distributed intercrystalline cracks in the interior of the specimen produced by opening of the grain boundaries. He further concluded that the stress action under these conditions was influenced by a large number of factors, and explained the results by introducing two strength properties, namely, the resistance to deformation (transcrystalline flow) and the cohesive strength (resistance to intercrystalline cracking) of the material. These two strength properties, however, were not constant, but varied as a function of the test duration. Besides being dependent on time they were influenced by the precipitation processes, which again depended on the creep process itself. Dr. Siegfried summarised the action of the various factors on the two strength properties as established by his tests, as shown in Table I.

The effects of a " V " notch on the tensile creep behaviour of a 0·5% molybdenum, 0·2% vanadium steel, within the temperature range 525°–650° C. and at stresses of 5–17 tons/sq. in., were discussed in a paper[4] by Messrs. R. W. Ridley and H. J. Tapsell (National Physical Laboratory). The form of notch used in these tests was 0·02 mm. deep, with a root radius of 0·25 mm. and an angle of 45° ; it was machined circumferentially round the centre of the test piece. It was considered to be reasonably representative of the sort of stress raisers that could occur in steam power components due to surface defects, as for example in the form of rough machining marks or grooves in bars or pipes. A comparison of the creep curves for these notched and unnotched test pieces of steel in the condition as air-cooled after 15 minutes at 1,000° C., suggested that if the permissible creep during service life were limited to 0·2–0·3% for temperatures of 600°–625° C., the existence of small surface defects would not be expected to produce a decrease in service life for the specified creep. It should be noted, however, that these conclusions are based on tests under symmetrical stress conditions, and do not necessarily apply for unsymmetrical stresses such as arise in bending.

Factors Involved in the Creep Process

One of the greatest drawbacks to a clear understanding of the creep process has been the large number of variables involved. It is, therefore, not surprising that much of the creep data available has been obtained under widely differing test conditions, so that it has been difficult to determine how the various factors involved affect deformation. Papers reviewing available data and giving the results of programmes of creep tests on various metals, designed to determine the precise function of the various factors involved in the creep process, were a most useful contribution to the Symposium.

It was recognised by several authors who made surveys of experimental results that points at which " breaks " in the log-log plots of stress versus rupture-life occur are indicative of critical conditions where a new cause of instability becomes active. Some of the causes suggested were : grain growth or boundary migration, recrystallisation, intergranular micro cracks, oxidation (intergranular), spheroidisation, or change in composition of segregated phases. These various causes and their influence on the mechanism leading to rupture were considered[5] by Dr. C. Crussard and M. J. Friedel (Institut de Recherches de la Siderurgie).

In their review[6] of the basic principles of a creep resisting alloy MM. A. Constant and G. Delbart (Institut de Recherche de la Siderurgie) summarised the various ways in which alloying elements may act :—

(1) by raising the temperature of recrystallisation of the base material, the most effective element

being that which raises this temperature the most ;

(2) by the presence of foreign atoms in solid solution in the lattice ; and

(3) by the formation of precipitates of additional phases : carbides, nitrides, or intermetallic compounds.

These authors gave special attention to the part played in resistance to creep by fine precipitates of additional phases, and the importance of heat-treatment by which the nature, size and distribution of these precipitates could be controlled. In addition to the precipitation originally present before creep occurs, they suggested that precipitates formed in the course of creep by a process analogous to secondary hardening could be most useful in improving creep resistance. The most suitable heat-treatments for producing structures amenable to secondary hardening under long-term creep conditions were investigated for a 0·15% carbon, 1% molybdenum, 1% chromium, 0·2% vanadium steel. Heating for two hours at 1,050° C. and cooling at a relatively slow rate of 300° C./hr. appeared to be a satisfactory heat-treatment for this steel. In this condition a specimen under a stress of 10·8 tons/sq. in. at 575° C. had not broken when the test was stopped after 3,200 hours with a creep strain of 6%.

In a paper[7] surveying both theoretical and experimental work concerning the effect of alloying on the creep of metals, Messrs L. Rotherham and C. R. Tottle (Department of Atomic Energy) suggested that although much remains to be done, particularly with regard to complex alloys, the relationship between alloying and creep behaviour appears capable of some degree of prediction already. They also suggested that recent theories such as were described by Prof. A. H. Cottrell,[8] concerning the important part played by the migration of solute atoms in determining resistance to plastic flow, may completely change views previously held concerning complex alloys, in which precipitation was considered to be the primary aid to creep resistance. Instead, it is now thought that for good creep resistance, the prime need is for the right solute atoms to be present, and that in some alloys more than one solute atom may be required to maintain the resistance to creep over the whole range of conditions required. This leads to properly designed " complex " alloys in which changes in metallographic structure, due to variation in composition and/or heat or mechanical treatment, may be secondary effects as regards creep resistance.

A study of how alloying affects the behaviour of grain boundary deformation and fracture in creep-rupture tests over a wide range of materials, varying in composition from high-purity aluminium to a complex age-hardenable gas turbine alloy, was the subject of a paper[9] by Prof. N. J. Grant (Massachussetts Institute of Technology). He found that, regardless of the purity or degree of alloying, log-stress/log-rupture-time, and log-stress/log-minimum creep-rate-curves indicated the tendency to intercrystalline cracking. Plots of true elongation, that is elongation up to second-stage creep, in general confirmed the incidence of grain boundary processes indicated by the log-log plots. Further evidence of the extent and nature of grain boundary deformation and of the amount of deformation in the grains themselves was obtained by metallographic examination. It was suggested that intercrystalline cracking is, in fact, a matter of relative rates of strain hardening versus recovery processes along the grain boundaries, and further that the properties of the grain boundary, to a certain extent, are the properties of the grain, but that imperfections on the boundary permit deformation processes to occur there preferentially at the higher temperatures.

Mr. I. I. Komilov (Academy of Science, U.S.S.R.) in his paper[10] surveyed the results of creep tests which he and his collaborators had made on solid solutions and compounds in various types of metallic systems. From the results of this work he was able to draw some general conclusions on the effect of composition and structure on creep strength. Of special interest was the author's simplified method of making creep tests under stresses caused by centrifugal force during rotation of the specimen ; a method which allowed the simultaneous testing of up to 24 specimens.

The contribution of metallographic studies to the understanding of creep mechanism was discussed by Prof. J. W. Freeman and Dr. C. L. Corey[11] (University of Michigan), and of special significance was the importance they attached to reactions involving carbon, nitrogen and/or oxygen in the mechanism controlling creep. In this respect it is significant that the most useful elements for improving creep resistance, such as vanadium, titanium and niobium, are all characterised by a very great affinity for carbon and nitrogen, and it is probably the solution of these compounds at the higher temperatures, and their reformation as a critical dispersion at the lower temperatures, that accounts for their usefulness. Attention was drawn to the notable effect of small amounts of boron applied alone or together with titanium, although in this case the mechanism is less certain and further investigation is desirable. It is also interesting to note that this paper provided some evidence to account for the pronounced effect of small amounts of aluminium (0·006–0·02%) in reducing the creep resistance of a low carbon steel, reference to which was made by Dr. Allen in his paper. From recent experimental work on a 0·15% carbon steel, it had been shown that creep resistance is primarily a function of the dissolved nitrogen content, the nitrogen combining with the aluminium and being precipitated when the steel is annealed below the coarsening temperature of the austenite.

Dr. C. H. M. Jenkins (National Physical Laboratory) gave an account[12] of some observations made in the course of laboratory studies on third-stage creep and fracture, which was illustrated by a selection of photomicrographs showing the mode of failure in pure iron, mild steel, 0·5% molybdenum steel, two nickel-chrome-molybdenum steels, and a copper-base alloy containing 3% of nickel and silicon. Examination under the microscope revealed that the mode of deformation is greatly influenced by such changes as hardening by alloy additions, recrystallisation, polygonisation, spheroidisation, age-hardening phase changes, and even graphitisation. The gradual onset of the effect of some of these factors, as well as the development of cavities and cracks, leads to tertiary creep. In some specimens the appearance of voids or cavities and their subsequent enlargement may be traced to grain boundaries, and would suggest that they are a forerunner of defects which lead to failure. The susceptibility of a material to recrystallise or to soften is important in the suppression of intercrystalline fracture, even though in some cases the cracks may already have been formed.

Slightly reduced in reproduction

Fig. 1.—Fracture after 985 hours: elongation 2%; reduction of area 3%. × 500

Slightly reduced in reproduction

Fig. 2.—Fracture after 430 hours: elongation 37%; reduction of area 78%. × 500

Longitudinal sections at 0·5 mm. from the fracture of bolt steels under a tensile stress of 15 tons/sq.in. at 525° C.

In a broad way, a correlation was found between the reduction in area and degree of elongation in ruptured specimens and the changes observed under the microscope for suitable ranges of temperature and stress. For example, low values for reduction in area and elongation were usually associated with intercrystalline cracking, as shown in Fig. 1. On the other hand, test pieces with high values for reduction in area and elongation, usually showed considerable recrystallisation and freedom from intercrystalline cracking, but sometimes contained cavities as shown in Fig. 2. Both photomicrographs are of nickel-chromium-molybdenum steels, of somewhat similar composition and cold tensile strength properties, which were considered for use as a bolt steel for high temperature service. The steel which behaved as shown in Fig. 1 was the better for this application, especially as its rate of creep, before the minimum rate was reached, was about one-tenth that of the other steel. These differences are ascribed to differences in molybdenum content, melting procedure and the nature of the hot working.

A general discussion of the events leading to intercrystalline failure in essentially single phase materials was the basis of a paper[13] by Mr. R. Eborall (British Non-Ferrous Metals Research Association). He concluded that intercrystalline fracture behaviour may be affected by viscous sliding of the boundaries, and by other factors involved in the fracture process itself, as well as by the hardness of the crystals, which has an important effect in raising the local stresses. The fracture characteristics of an alloy may be greatly affected by small alloying additions, improved properties being obtained by adding high melting-point elements of an " unfavourable " size factor.

Dr. R. D. Johnson, Dr. A. P. Young and Dr. A. D. Schwope (Battelle Memorial Institute) used X-ray diffraction techniques and the electron microscope to investigate the creep characteristics of high purity aluminium in the temperature range 204–482° C., and under conditions of constant resolved shear stress.[14] The complex nature of the slip bands and the tendency to kinking was observed in single crystals of two different purities. A fine sub-structure, similar to that observed in annealed polycrystalline aluminium, was detected in annealed single crystals of aluminium. This structure has linear dimensions of the order of 1μ, the predicted size of the mosaic structure, and is of importance on theoretical grounds because it raises the question of the distribution of dislocations in the annealed crystals.

Development of Creep-Resisting Alloys

Dr. Allen, in his paper[1] indicated that the most notable advances in the development of new creep-resisting materials for use at very high temperatures had been in the field of sintered complexes consisting of hard carbides or oxides bonded with metal or alloy. Materials of this type had withstood a stress of 2¼ tons/sq. in. at 1,200° C. for over 900 hours with less than 1% elongation, and 4 tons/sq. in. at 1,000° C. for a similar period. When it is realised that present-day commercial creep-resisting alloys show a similar behaviour only at the lower temperature of 850° C., this represents a considerable advance in ability to resist deformation. The brittleness of these new materials has, however, so far precluded them from successful application in gas turbines. Further study into the mechanism of flow and fracture in this type of material appears to be well worthwhile, since it may provide useful information for the development of creep-resisting materials. It is also possible that further light on the mechanism of creep resistance at a lower range of temperatures (250–400° C.) is given by the behaviour of sintered aluminium powder (SAP), which consists of extremely fine particles of alumina dispersed through a matrix of aluminium. Compared with the best orthodox creep-resisting aluminium alloys, SAP shows a marked superiority in creep strength at temperatures above 250° C. There is little doubt that the differences in behaviour in this case are due to the fact that the dispersed constituent in SAP is stable at high temperatures, whereas the dispersed

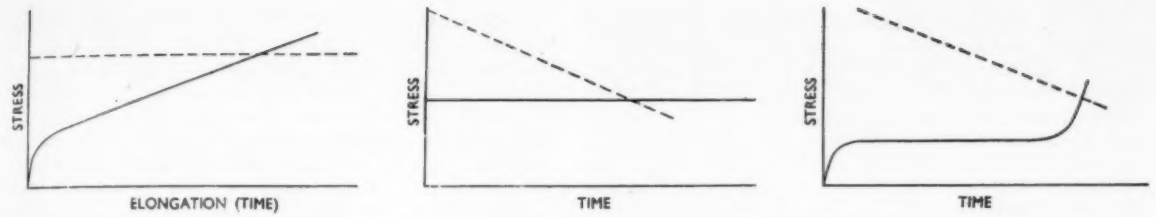


Fig. 3.—Basic distinction between the various methods of material testing: (*a*) tensile test at room temperature; (*b*) alternating fatigue test; (*c*) creep test. In each case the dotted curve is the cohesive strength, the continuous curve the effective stress, and the intersection the point of fracture.

hardening constituent in the normal alloy at temperatures above 250° C. first agglomerates and then the coarse particles tend to dissolve in the matrix.

To meet the demand for improved gas turbine compressor materials in the temperature range 300–500° C., interest in recent years has centred on titanium, with a vigorous search for titanium alloys having good strength and satisfactory creep resistance. The interesting feature of this search is the connection between the low elastic modulus of titanium and its creep resistance, and the remarkable effect of the addition of aluminium in raising the elastic modulus and in improving the strength properties of titanium alloys at moderate temperatures.

Mechanism of Creep Processes

The basic principles underlying the creep test and how it differs from other types of tests such as the normal tensile test and the alternating fatigue tests were illustrated by Dr. Siegfried,[3] as shown in Fig. 3. It will be seen that there is a fundamental difference between the tensile test and the alternating fatigue test: in the first, the strength of the metal (cohesive strength), as a first approximation, can be considered to remain constant while the load is variable; in the second, the load remains constant but strength diminishes during the test, fracture occurring when it has been reduced to the level of the stress due to the load. The creep test differs from both of these in that although the total load is kept constant the strain which occurs brings about an increase in stress: the effective stress is a function of time and runs parallel with strain, following the course shown in Fig. 3*c*. This time-strain curve is normally divided into three stages: Stage 1 with decreasing rate of creep; Stage 2 with constant rate of creep (strengthening and weakening factors being in equilibrium); and Stage 3 with a marked rise in the rate of creep. During this test the strength of the metal falls off continuously, approximately as shown in Fig. 3*c*. It is clear that in the case of the creep test, conditions are not so simple as in the other tests, since we are dealing with time dependent functions.

The Symposium revealed, in the main, two basically different approaches to the study of the mechanism of creep. On the one hand there was the "theoretical" approach, in which the rate-determining processes can be represented by models based on the dislocation theory; and on the other hand the "experimental" approach by which the process of creep is built up from observations of the effects of deformation on the structural and strength characteristics of metals and alloys.

In his paper[15] on "Creep Processes" Dr. W. A. Wood (Baillieu Laboratory, University of Melbourne) adopted the latter approach, regarding creep as one aspect of the general problem concerned with why the mechanical properties of a metal depend on how it is deformed. The structural changes that occur in the standard tensile test at room temperature were taken as a basis for studying the changes peculiar to slow straining at elevated temperatures (creep). Dr. Wood concluded that the latter process introduces new structural features, described as stress recovery, equilibrium flow and boundary flow. The comparison between the two processes also showed that extension during creep should be divided into two components: boundary flow, and grain elongation; recognition of these components simplified such problems as the apparent absence of strain-hardening in creep, and the tendency to slipless flow.

Some ideas on the rate-determining process in creep were put forward by Prof. N. F. Mott (University of Bristol)[16]. After considering current ideas on the nature of work-hardening, he discussed steady-rate creep in pure metals, and considered how far it was possible to account for some of the facts of creep in terms of the movement of dislocations. He assumed that steady-state creep was due to "slip" and that the process which prevented the dislocations from accumulating in the material and so work-hardening it, was polygonisation, as was shown by the experiments of Wood and McLean. Of the two hypotheses put forward to explain polygonisation, namely, "climb" of dislocations and "slip," he concluded that the latter was the more likely, in which case the rate-determining process must be "slip."

Prof. J. E. Dorn (University of California), gave a critical analysis of some fundamental experiments on high-temperature creep.[17] He suggested that two alternative mechanisms for creep might exist, one predominant at temperatures above that for rapid crystal recovery (about half of the melting temperature for high purity metals) and the other, for lower temperatures. While considered to be not the only factor responsible, Prof. Dorn showed that high creep-resistant metals occurred among those transition elements which exhibited the highest activation energies for creep and self-diffusion, and that the activation energies for high-temperature creep appeared to agree with those for self-diffusion. From this, it was concluded that high-temperature creep is not due to thermal activation of dislocation over a barrier but rather occurs as a result of dislocation "climb" by the self-diffusion process. It was also shown that the activation energy for grain boundary shearing is practically identical with that for the total creep strain.

DR. D. MCLEAN (National Physical Laboratory) discussed[18] some experimental data for aluminium and aluminium alloys which led to the fairly firm conclusion that, in the case of these metals, the slip process predominates to the virtual exclusion of a diffusion mechanism over the temperature range 200–400° C. He also showed that the rotation of subcrystals (i.e., cells into which the grains split up during creep) is proportional to the elongation, from which it was deduced that practically all the crystal deformation occurred by a normal glide process. Further, the amount of grain boundary sliding occurring in aluminium and copper during creep was also shown to be proportional to elongation, suggesting that a linear interaction existed between crystal slip and grain boundary sliding.

The mechanism of grain boundary displacement and its relation to the creep process as a whole was the subject of a paper[19] by PROF. F. N. RHINES (Carnegie Institute of Technology) read by Dr. Epremian of the American Embassy. This was supported by experimental observations based on the tensile creep behaviour of pure aluminium bicrystals.

The tertiary stage of creep appeared to be more difficult to account for. DR. D. CRUSSARD and M. J. FRIEDEL (Institut de Recherches de la Siderurgie)[5] showed that rupture occurred through the slow formation of intergranular micro-cracks, which itself resulted from some intrinsic mechanism related to the recovery process occurring during creep. The production of an excess of vacancies through the " climb " (diffusion) of dislocations, or the crossing of dislocations of different glide systems, was suggested as a possible mechanism.

The processes leading to brittle or ductile fracture were explained by DR. A. KOCHENDORFER (Max Planck Institut fur Eisenforshung)[20] in terms of the static and dynamic features of dislocations. Suitable arrangements of dislocations were considered to lead to the break-up of the lattice if their energy was greater than the surface energy of the " holes " produced, a hole of this type being equivalent to a crack. A crack of atomic dimensions could be produced by a pile of single dislocations, and grow to microscopic dimensions by means of further dislocation, the Griffith mechanism then leading to a brittle fracture. Because of the strong repulsive forces between dislocations of the same sign, this was considered only possible if the dislocations were accelerated by the external shear stress to about 90% of the velocity of sound. It was considered that this happened at normal stresses providing the movement of the dislocations could go on undamped. There was some uncertainty about this but it was assumed to be so. If the conditions for a sufficiently high acceleration of the dislocations were not fulfilled, plastic flow took place followed by ductile fracture. In this case a crack of atomic dimensions was formed by condensation of vacancies produced by the dislocations and grew by addition of dislocations until it reached the Griffith length.

MR. Y. N. RABOTNOV (Academy of Science, U.S.S.R.) proposed[21] a mechanical theory of one-dimensional creep in which he aimed to establish mathematically some dependence between stress and strain, giving prime consideration to the essential non-linearity of the process and the non-recoverability of the greater part of the deformation.

A formula for the creep curve which agreed very accurately with the observed curves for Nimonic 80A was given in a paper[22] by DR. W. BETTERIDGE (Mond Nickel Co., Ltd.), in which he showed that short-period low-stress torsional creep tests carried out in the course of normal tensile creep experiments on Nimonic 80A indicated that the number of available strain-promoting centres increased linearly with the tensile strain resulting from such centres, and thus led to the accelerating creep rate known as tertiary creep.

Considering these two methods of approach, namely " theoretical " and " experimental " it may appear at first sight that they have little in common, but the important outcome of this Symposium was that both were leading to a better understanding of creep processes, although much work remained to be done before a mechanism was developed capable of enabling alloys with known creep properties to be designed. In answer to the question of how far we are from this goal it was suggested by some that it may be five or ten years hence, by others that already creep behaviour was capable of some degree of prediction. Certainly some of the papers revealed how closely the two concepts had approached. In this respect the considerable progress made since 1946, should be a source of great encouragement to all workers in this important field.

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2 Note on the fracture under complex stress creep conditions of a 0·5% molybdenum steel at 550° C. and a commercially pure copper at 250° C. A. E. JOHNSON (Mechanical Engineering Research Laboratory) and N. E. FROST (National Physical Laboratory).
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4 The effect of a " V " notch on the tensile creep behaviour of a molybdenum-vanadium steel. R. W. RIDLEY and H. J. TAPSELL (National Physical Laboratory).
5 Theory of tertiary creep and fracture. C. CRUSSARD and M. J. FRIEDEL (Institut de Recherches de la Siderurgie).
6 Basic principles of a creep-resistant alloy. G. DELBART and A. CONSTANT (Institut de Recherches de la Siderurgie).
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9 Grain boundary participation in creep deformation and fracture. N. J. GRANT (Massachussetts Institute of Technology).
10 Creep properties of solid solutions and compounds in metallic systems. I. I. KOMILOV (Academy of Science, U.S.S.R.)
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14 Plastic deformation of aluminium sngle crystals at elevated temperatures. R. D. JOHNSON, A. P. YOUNG and A. D. SCHWOPE (Battelle Memorial Institute).
15 Creep processes. W. A. WOOD (Universitity of Melbourne).
16 A discussion of some models of the rate-determining process in creep. N. F. MOTT (University of Bristol).
17 Some fundamental experiments on high temperature creep. J. E. DORN (University of California.)
18 Interaction between crystal slip and grain boundary sliding during creep. D. MCLEAN (National Physical Laboratory).
19 Mechanism of grain boundary displacement. F. N. RHINES (Carnegie Institute of Technology).
20 A theory of brittle and ductile fracture, with application to creep fracture, based on the dynamic behaviour of dislocations and condensation of vacancies. A. KOCHENDORFER (Max Planck Institute, Germany).
21 Creep under varying Loads. Y. N. ROBOTNOV (Academy of Science, U.S.S.R.)
22 Tertiary creep of creep-resisting nickel-chromium base alloys. W. BETTERIDGE (Mond Nickel Co., Ltd.).

GEORGE KENT, LTD., and Foxboro-Yoxall, Ltd., announce that they have made arrangements for mutual marketing of the Foxboro d/p cell and the Kent oxygen analyser in the United Kingdom. Foxboro selling of the Kent oxygen analyser may later be extended to the United States.

THE 7th German Handicrafts and Trade Fair will be held in Munich with international participation, from 5th-13th May, 1955.

The Safety Factor in the Design of Seamless Steel Gas Cylinders

By S. E. Mitchell

(Communication from the Mechanical Engineering Research Laboratory)

Several methods are in use for the application of the safety factor in the design of seamless steel cylinders for holding compressed gases. The author discusses the merits of each before putting forward a proposal for a common basis for deriving the working stress.

MILLIONS of seamless steel gas cylinders are used to store and convey highly compressed oxygen, nitrous oxide, carbon dioxide and other gases. The designer of such cylinders must adopt some value for the working stress, and he is often both guided and limited in his choice by statutory regulations, or by a recognised specification. The value will not be the same for all materials of construction: a lower stress, for example, would usually be allowed in a mild-steel than in a nickel-chromium-molybdenum-steel cylinder. The specified working stress is derived from a property, such as the tensile strength, determined by mechanical tests on samples, and the number by which the stress determined under test is divided to obtain the working stress is customarily termed the "safety factor."

The following discussion, based on papers presented to the Home Office Gas Cylinders and Containers Committee (1946) and the British Standards Institution Secretariat Panel (I.S.O.) on Gas Cylinders, outlines the application of the safety factor in the design of seamless steel gas cylinders, and suggests a possible unification of the diverse methods now in use. Following a description of the methods and the arguments in their favour, a proposal is made for a common basis for deriving working stress.

Outline of Present Practice

The Function of the Safety Factor

The design of a gas cylinder is based on limited data bearing a relation to some of the more obvious influences to which it will be subjected in the course of service. Separate allowances are usually made for corrosion and for external loading (e.g., due to storing the cylinders in piles). Corrosion is generally allowed for by an extra thickness added to that required for other purposes, and external loading by a limiting minimum thickness.

Apart from these allowances, the wall thickness is calculated from a permissible stress figure. Some designers maintain that this stress should be set at a given fraction of the yield stress of the material used; others that the stress calculated at the hydraulic test pressure (equal to some given multiple of the maximum working pressure) should not exceed a certain value; and others that the stress should be set at a given fraction of the tensile strength of the material used.

A safety factor represents an attempt to allow in terms of a practical testing technique for a very large number of unpredictable variations in service conditions. Besides simple stress, these may include small deformations; various combinations of stress and strain; impacts; vibration and temperature changes which may cause fluctuations of stress; manufacturing variations in dimensions; and, perhaps, varying degrees of misuse depending upon the intelligence and scrupulousness of the user. No single property determined by mechanical test is an infallible index of the behaviour of the cylinder in service. It is not imagined, because the calculated working stress in the wall of a cylinder is required not to exceed, say, one-third of the tensile strength, that service conditions will be liable at the worst to induce a stress of three times the calculated working stress, and to make no other demands on the cylinder. The test which is to serve as the basis for applying a factor of safety should, therefore, be the one that is the best index of the general resistant qualities of the material.

Gas cylinders can be divided into two classes. The first class comprises cylinders for permanent and high-pressure liquefiable gases. These are nearly always operated at a comparatively high internal pressure, and normally the wall thickness needed to resist this pressure will make the cylinder stout enough for all ordinary loading and handling. The second class comprises cylinders for low-pressure liquefiable gases. In these, resistance to external loads and handling acquires greater relative importance; and the manufacture of cylinders which are very thin in relation to their diameter may be impracticable. The necessary wall-thickness is governed by these factors rather than by the internal pressure.

Working Stress Related to Yield Stress

A constant factor of safety applied to the yield stress finds favour in some quarters. By this method, very light cylinders can be designed in alloy steels, and light alloys, treated to raise the yield stress to a high value. The yield stress may, indeed, be very close to the tensile strength. The term "yield stress" is used loosely, and in materials that do not show the yield phenomenon of mild steel denotes a proof stress corresponding to 0·2%, or some other small percentage, of permanent strain.

Materials with the high proof stress may, however, save little or no weight in cylinders for low-pressure liquefiable gases, where, as explained above, the minimum practicable thickness depends largely on rigidity and manufacturing limitations.

Working Stress Related to Hydraulic Test Pressure

When cylinders are designed to a stress calculated at the hydraulic test pressure, and when this pressure is a simple multiple of the working pressure, there is no difference in principle from designing to the stress at the working pressure. The factor of safety is still applied to the yield (or proof) stress, or to the tensile strength, as the case may be.

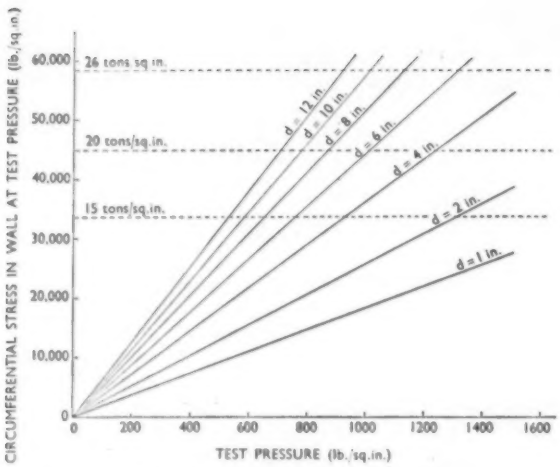


Fig. 1.—Seamless cylinders for L.P. liquefiable gases ($t = 0{\cdot}027\sqrt{d}$): stress produced by test pressure in cylinders of various diameters.

The hydraulic test pressure is, however, not always made a simple multiple of the working pressure. A value of one-and-a-half times or twice the working pressure does not provide a very searching test on cylinders for low-pressure liquefiable gases, and the stringency of the test varies with the working pressure and with the diameter of the cylinder. For this reason, a hydraulic test pressure is often advocated which will induce in the wall of the cylinder a stress not far short of the yield stress. This test pressure is calculated on the design wall thickness of the cylinder, and the test is carried out as a stretch test—i.e., the permanent expansion of the cylinder is observed. Excessive permanent expansion indicates some deficiency, such as insufficient wall thickness, in the cylinder.

Where the hydraulic test pressure is chosen in this way to give a stress approaching the yield stress and not directly related to the stress at the normal working pressure, it is not usually employed as a design factor—probably because internal pressure of any kind is not, in this case, of primary importance in design.

For cylinders for permanent and high-pressure liquefiable gases the hydraulic test pressure can be expressed as a multiple of the working pressure and still, in actual fact, induce a stress in the cylinder wall approaching the yield stress of the material. Here, if the design formula includes the stress at the test pressure, the yield stress is the implied criterion.

In cylinders made from materials of high yield strength, the pressure required to apply a stress approaching the yield may be beyond the range of commonly available apparatus, and a lower test pressure is sometimes adopted as a matter of expediency. In such circumstances, even if the design formula included the stress at the test pressure, the factor of safety would not necessarily be applied to the yield stress. The test pressure would be, in effect, arbitrarily chosen, and by the inclusion of a suitable multiplying factor in the design formula the working stress could be related to either the yield stress or the tensile strength.

Working Stress Related to Tensile Strength

A factor of safety applied to the tensile strength is regarded by its advocates as the best practical means of relating the design of the cylinder to the general resistant qualities of the material used. It is true that a material might have a very high tensile strength and yet be very brittle, but common-sense precautions, such as the stipulation of a minimum elongation in the tensile test, are assumed.

In view of this, the " factor of safety " applied to the proof (" yield ") stress in a material in which this proof stress is close to the tensile strength is regarded as somewhat artificial; for the factor of safety on the tensile strength is in that case very little more than the factor of safety on the proof stress, whereas in mild steel it may be nearly twice the factor of safety on the yield stress. Moreover, an increased proof stress in any material may be accompanied by a decreased impact resistance. Experience has shown, also, that, with alloy steels and light alloys, an increased proof stress is not necessarily accompanied by an increased fatigue resistance, and therefore does not always justify a higher working stress.

Proposals for a Common Basis

The values of working stress in the design of gas cylinders differ to some extent in different countries and for different materials of construction. The present discussion assumes the following formula for the calculation of wall thickness:

$$t = \frac{pd}{2s-p}, \text{ with a minimum thickness of } 0{\cdot}027\sqrt{d},$$

where t = minimum wall thickness (in.) at any point;
p = internal working pressure (lb./sq. in.);
d = inside diameter (in.) of cylinder;
s = maximum permissible stress (lb./sq. in.) in cylinder wall at working pressure.

It is proposed that for seamless steel gas cylinders the value of s in this formula shall be some given fraction of the tensile strength of the steel.

The ratio of working stress to tensile strength is in the neighbourhood of one-third in many specifications; in other words, the safety factor on the tensile strength is about 3. A working stress of one-third of the minimum of the range of tensile strength specified for the steel used is now proposed as a normal maximum in seamless gas cylinders. For certain steels, however, a higher ratio of working stress to tensile strength might be permissible if it were shown by experience to be justified.

Relation of Proposals to Present Practice

Apart from special modifications to cover external loading, the formulae at present in use for relating internal pressure to stress in the wall are of two main types. One is fundamentally the same as that given above, though the minimum-thickness requirement may differ. The other, prescribed in the American and Canadian regulations, is:

$$S_p = \frac{P(1{\cdot}3D^2 + 0{\cdot}4d^2)}{D^2 - d^2}$$

where P = internal pressure (lb./sq. in.);
S_p = stress (lb./sq. in.) in cylinder wall at pressure P;
D = outside diameter (in.) of cylinder;
d = inside diameter (in.) of cylinder.

This formula is based on the now discredited maximum principal strain criterion of elastic failure; S_p is not an actual stress, but is the tensile stress which acting alone would give the same maximum principal strain as that in a cylinder of the given dimensions under the given pressure. The ratio s/S_p depends on the ratio of thickness to diameter; it is equal to $1{\cdot}17$ when the ratio of

TABLE I.—WORKING STRESS PERMITTED IN VARIOUS COUNTRIES IN SEAMLESS STEEL CYLINDERS FOR PERMANENT GASES

Country	Steel	Maximum Allowable Ratio of Working Stress to Tensile Strength
U.S.A. and Canada: working pressure up to 900 lb./sq. in.	Spec. 3A and 3AA	$\frac{Sp}{T} = \frac{14{,}400}{T \text{ in lb./sq. in.}}$ ($\frac{s}{T}$ = a higher value—see text*)
U.S.A. and Canada: working pressure over 900 lb./sq. in.	Spec. 3AA	$\frac{Sp}{T} = 0{\cdot}4$, but max. $S = 42{,}000$ lb./sq. in. ($\frac{s}{T}$ and corresponding over-ruling maximum are higher—see text†)
France	All normally permitted varieties	0·33
Belgium	Carbon Alloy	0·3 to 0·375 0·45
Switzerland (internal traffic)	Carbon Alloy	0·325 0·4
Switzerland (international traffic)	Carbon Alloy	0·29 0·36
Germany	All normally permitted varieties	0·31
South Africa	Low Carbon High Carbon Manganese Alloy	0·37 0·265 0·41 0·42
Great Britain	B.S.400 (low carbon) B.S.399 (high carbon) B.S.1045 (manganese)	0·32 0·30 0·34

* The highest value of $\frac{s}{T}$ in practice would probably be 0·38, when $\frac{s}{Sp} = 1{\cdot}17$ and tensile strength = 44,800 lb./sq. in. (20 tons/sq. in.).

† The highest value of $\frac{s}{T}$ in practice would be 0·47, when $\frac{s}{Sp} = 1{\cdot}17$; but s cannot exceed 49,100 lb./sq. in. (22 tons/sq. in.).

thickness to diameter is negligible, and decreases as this ratio increases, becoming, for instance, 1·04 when thickness/diameter = 1/10.

Table I* shows the working stress permitted in various countries. The stress has been expressed in terms of the tensile strength (T) of the material of construction.

If a stress at design pressure of one-third of the tensile strength were adopted in cylinders for certain high-pressure liquefiable gases, some of the present test pressures would require modification to avoid producing a stress above, or too closely approaching, the minimum stipulated yield point in some steels.

For cylinders for low-pressure liquefiable gases, which can be taken as having a design pressure not greater than 500 lb./sq. in., the over-ruling minimum requirement (t not less than $0{\cdot}027\sqrt{d}$) will operate for all values of d which are practical for seamless cylinders, i.e., values of d not greater than 12 in. If a fixed test pressure is specified for any given liquefiable gas, as it is in several countries, the stress at the test pressure varies with d, and under certain conditions might exceed the minimum yield of the material. Fig. 1 illustrates this point. Horizontal lines representing possible minimum yield stresses of 15, 20 and 26 tons/sq. in. are drawn to cut the oblique lines which give the stress at any test pressure up to 1,500 lb./sq. in. in cylinders of various internal diameters. As an example, the test pressure for a hydrogen sulphide cylinder according to the Swiss regulations is 54 atm. = 790 lb./sq. in.; the stress produced would exceed 15 tons/sq. in. in a cylinder of 6 in. internal diameter, and 20 tons/sq. in. in a cylinder of 10 in. internal diameter.

A uniform value of not more than one-third for the ratio of working stress to tensile strength could, therefore, only apply to cylinders for liquefiable gases if test pressures were calculated, according to the material and dimensions of cylinders, to produce some prescribed stress.

* The values in the table are based on information collected by Messrs. F. S. Marsh and C. Twigg, of the Chesterfield Tube Co., Ltd. Sp denotes the working stress, calculated by putting $P = p$, and not the stress at the test pressure specified in the American and Canadian regulations.

Acknowledgments

The work described was carried out in the Mechanics and Materials Division of the Mechanical Engineering Research Laboratory as part of the research programme of the Mechanical Engineering Research Board. It is published by permission of the Director of the Laboratory.

International Mechanical Engineering Congress

IT has been decided not to hold the Sixth International Mechanical Engineering Congress until 1955, but in conjunction with the Fourth European Machine Tool Exhibition, which is being held in Milan from 13th to 23rd September, a Colloquium at Stresa has been planned for the 24th to 25th September, on "Automation of Measuring."

Further particulars can be obtained from The British Engineers' Association, 32, Victoria St., London, S.W.1.

Copper-Base Alloy Castings Inspection Procedure

THE Ministry of Supply and the Association of Bronze and Brass Founders have recently agreed on the terms of "A Code of Procedure to Facilitate the Co-ordination of Inspection for Copper-Base Alloy Castings Ordered by the Ministry of Supply." The inspection procedure set out in the Code, which will come into force on the 1st September, 1954, will apply to all Ministry of Supply contracts and the sub-contracts arising from them, for copper-base alloy castings. Not only founders, but all Ministry contractors and sub-contractors will require copies of the Code which will be available to non-members of the Association at a price of 5s. per copy, post paid. Applications should be sent to the Secretaries, of the Assocation, Heathcote & Coleman, 69, Harborne Road, Edgbaston, Birmingham, 15.

Correspondence

PRESENTING A TECHNICAL PAPER

The Editor, METALLURGIA.

Sir,

May I assure aspiring authors that a speaker on a technical subject who cannot talk for an hour from brief notes does not properly know his subject. It is, however inadvisable to talk for as long as one hour; three quarters of an hour is sufficiently long, and if possible it is desirable not to show more than say twelve lantern slides.

Yours faithfully

Isleworth,
28th July, 1954

J. Ferdinand Kayser,
Gillette Industries, Limited.

Casting Metals in Plaster Moulds

Superior Finish and Dimensional Accuracy

THE idea of using plaster as a mould material is not new, but it is only in recent years that the process has had any commercial significance. The castings made by this method are superior to sand castings from the point of view of surface finish, dimensional accuracy, and fineness of detail, and they have a more solid structure. These improvements are, however, only achieved at increased cost.

Plaster moulding employs the match-plate system, cope and drag assembly, separate cores and gravity pouring. The moulds, like sand moulds, are capable of producing one casting only, and in sizes which are comparatively small. For this reason, the process is somewhat limited in its application, and should be regarded as one of the speciality moulding techniques. Ceramic moulds—made up from refractory materials, such as glass, porcelain enamel, and fused clay products—are capable of producing more than one casting, and although the process has not been used to any great extent, interesting developments along this line may be expected.

The plaster process has occasionally been used for producing aluminium alloy castings, when gypsum plasters are suitable. It is usual to limit the process to castings weighing less than 2 lb., but it is quite feasible to produce larger castings provided the necessary facilities are available. Gravity pouring is generally used, but moderate pressures have been applied to give better casting detail.

Moulding Technique for Copper Alloys

Plaster moulding has found its greatest application in the production of copper-base alloy castings, and in this field the mould material used consists of 70–80% plaster-of-Paris mixed with 20–30% fibrous strengthener (magnesium silicate), and a small addition of impurities (salts and hydrochloric acid) to speed-up the setting process. More water than is required to set the plaster is added for reasons which will be apparent. The plaster mixture is poured round the pattern and allowed to proceed as far as the semi-set stage before removing the pattern to produce the mould cavity.

After the mould impressions are complete, the cope and drag halves are baked separately to drive off moisture, the removal of the excess water leaving a labyrinth of interconnected holes, which serve to vent the mould. The wet mould should be dried with a minimum of air circulation, and the initial temperature may be as high as 800° C. A continuous radiant-heat type of baking oven is desirable, with the temperature gradually decreasing to about 95° C. at the discharge end. The complete time cycle depends on the size of the mould, varying from 1½ to 2½ hours for mould sections of 1½ to 2¼ in. high. The dried moulds have a compressive strength of 8–20 lb./sq. in., depending largely on the ratio of water to solid material in the original mixture. The baking operation is probably the most critical stage in mould production, as, unless it is carried out correctly, the mould may crack, or gases may be released which would spoil the casting.

Since the thermal conductivity of a plaster mould may be only one-tenth of that of a green sand mould, the solidification of the molten metal takes place more slowly than is the case in sand moulds or permanent moulds. This is advantageous, in that it allows the production of castings with thinner sections, and there is less danger of internal porosity. On the other hand, segregation in some alloys is greatly accentuated by slow cooling, and the mechanical strength is likely to be lower, especially in the case of materials prone to grain growth, like aluminium. Furthermore, due to the high mould strength, hot tearing may also be a problem.

Features of the Process

Dimensional tolerances depend on the accuracy of the pattern and, to some extent, on physical factors involved in the process. It should be possible to maintain an overall tolerance of ±0·010 in., and of ±0·005 in. on small dimensions. Outside surfaces should have a draft angle of ½°, while inside surfaces may require this figure to be increased to 3°, depending on the shape.

From the metallurgical standpoint there are a number of interesting features in the plaster moulding process.

(1) Special care is taken in the construction of these moulds to ensure that the material of which they are made yields as the metal cools, as otherwise stresses would be produced in the contracting metal, and cracking might result.

(2) The water content in the moulds is reduced to a point where no bubbling or turbulence occurs when the metal is poured. Volatile materials are eliminated at the drying stage.

(3) Hydraulic and pneumatic conditions in the mould may be duplicated, and such factors are not critical in regard to the temperature of the metal, nor the period of moulding.

(4) The orifice inlet to the mould cavity may be small, and the pouring time lengthened to 6–10 times that required in sand casting. In consequence risers can be proportioned accurately to eliminate shrinkage.

(5) Directional solidification can be controlled.

It is generally held that, in the long run, it is cheaper to use one of the proven techniques rather than attempt to develop one's own. For the most part they are patented, and full information on methods and materials can be obtained from the firms competent to grant manufacturing rights.

Plaster moulding is in the development stage, and at the present time production costs are high due to the specialised procedures involved. The process is probably most suitable for the production of parts wanted in moderate quantities, which would require considerable machining if made as sand castings, and whose limited production would not justify the high costs involved in the production of permanent moulds. Typical applications include intricate parts which call for close dimensional tolerances such as gear teeth, ratchet teeth, stops, cams, levers, and parts requiring fine marking or lettering on the surface of the casting.

NEWS AND ANNOUNCEMENTS

Fuel Efficiency Refresher Course

ORGANISED for works and plant engineers by The National Industrial Fuel Efficiency Service, with the support of The Southern Regional Council for Further Education, a residential refresher course on "Fuel Efficiency as an Aid to Production" will be held at the Clarendon Laboratory, Oxford, with accommodation at Brasenose College, from 27th September–1st October, 1954.

Eleven lectures will be given, each by an expert in the special field to be covered: "The Economics of Fuel Selection"; "Combustion Control in Practice"; "Instrumentation and Automatic Control"; "Heat Storage and Peak Loads"; "Heat Balances in Practice"; "Compressed Air Appliances and Practice"; "Design, Performance and Operation of Power Plant"; "The Control of Power Factor and Maximum Demand"; "The Diesel Engine and Waste Heat Recovery"; "The Handling and Storage of Fuel"; and "Fuel Efficiency in Europe and the U.S.A."

There will be opportunities for questions and discussions and a visit will be made to an industrial concern. The Right Worshipful the Mayor of Oxford will welcome students and the opening address will be given by Air Chief-Marshal, Sir Leslie Hollinghurst, K.C.B., C.B.E., D.F.C., Chairman of N.I.F.E.S. The closing address will be given by Lt. Gen. Sir Thomas Hutton, K.C.I.E., C.B.E., M.C., of the British Productivity Council.

Application forms and a brochure giving full details of speakers and lecture contents will be available from 16th August, 1954, and may be obtained on application from: The Secretary to the Course, Southern Area, N.I.F.E.S., T.O.B. II, Whiteknights Park, Earley, Reading. (Tel.: Reading 61122, Ext. 165). The fee for residential students (including course fees, accommodation, all meals and copies of lecture notes) will be 8 guineas, and for day students (including course fees, coffee, lunch, tea and copies of lecture notes), 4 guineas.

National Industrial Foot Safety Week

THE prime object of National Foot Safety Week, which is scheduled for 25th–30th October, 1954, is to encourage factory workers to wear suitable footwear while at work. At first glance it may seem unnecessary to organise a special compaign week—backed by all the propaganda and advisory services of The Royal Society for the Prevention of Accidents and the local Industrial Safety Groups — to achieve such an apparently simple result. However, a study of the present problem will make the reason for the campaign abundantly clear.

The general attitude of most workers is that their old shoes—no longer smart enough for outside wear—are good enough for work. The idea of buying a pair of boots or shoes specially for work appeals to very few industrial workers. As a result, no less than one quarter of all industrial accidents cause injury to the feet or toes. Some of the accidents are very serious causing permanent lameness or even necessitating amputation of the injured foot. In consequence, the sum total of human suffering, the loss of earnings to the worker, and the loss of production to the country places a heavy burden on the national economy.

The accidents are caused by the defective or unsuitable footwear being worn by the worker. Worn soles permit of the penetration by nails or other sharp objects. Loose soles can trip the wearer, which is particularly dangerous if the worker is on stairs, a ladder or on scaffolding. Worn heels lead to stumbling, fatigue and general unsteadiness. Women's heels are unsuitable if excessively high. Soft or flimsy shoes give no protection against heavy objects which fall or are accidentally dropped on the feet. But despite all the hazards to which the feet are exposed, it is not uncommon to see both men and women at work in heavy industry wearing cast-off dance shoes.

The campaign will not try to encourage all workers to wear a particular type of footwear—the jobs in industry are too varied for any one type to be suitable for all—but it *will* encourage the wearing of the right type for the particular job being done: rubber boots where necessary, steel toe-caps where necessary, or just ordinary strong walking shoes. The campaign also stresses the importance of keeping all footwear in a good state of repair.

The Royal Society for the Prevention of Accidents, which is organising the campaign, has prepared special posters and leaflets to encourage workers to protect their feet. The Society has also invited Civic Heads and Chambers of Commerce throughout the United Kingdom to give their support to the campaign. Many of the local Industrial Safety Groups will be making special efforts during Campaign Week to achieve an appreciable reduction in the number of foot accidents. H.M. Chief Inspector of Factories has expressed his sincere wish for the success of this important accident prevention effort.

Corrosion of Structural Steelwork

A CRITICAL abstract of the first five sets of "Specifications for Cleaning and Painting Steel Structures," issued by the Steel Structures Painting Council of Pittsburg, U.S.A., is available free of charge from B.I.S.R.A., Corrosion Section, 140, Battersea Park Road, London, S.W.11. The abstract was originally prepared by Dr. J. C. Hudson, Head of the B.I.S.R.A. Corrosion Section, for the Corrosion and Electrodeposition Committee of the Inter-Service Metallurgical Research Council. The five sets comprise 28 individual specifications, dealing respectively with surface preparation, pretreatment, paint, paint systems, and paint application.

The Steel Structures Painting Council of America has come into existence in the United States within the last few years. It comprises representatives of about twenty prominent American organisations, including the service departments, railroads, research establishments and trade associations. Its tasks are:

(1) To determine and outline the best methods of cleaning and painting steel structures.
(2) To issue, if possible, a code or specification covering practical and economical methods of surface preparation and painting steel structures.
(3) To perform or to further research on the corrosion of steel structures.

(4) To issue recommendations on the protection of steel structures; such recommendations to be made available to specification and to code writing committees.

In many respects the Council is not very different from the British Corrosion Committee. But it differs from the Committee in the fact that the engineering institutions are officially represented, in its restriction to the structural field, and in the emphasis given to the preparation of a code of practice. While there is nothing revolutionary or even controversial in any of these specifications, the Council has performed a very valuable service in thus studying and codifying all recent developments in its field into a logical and coherent sequence. Although the specifications can no doubt be improved, their general adoption just as they stand would do much to eliminate the unnecessary wastage of steel and money that still occurs through ignorance or neglect of the elementary features of correct, practical corrosion prevention.

Symposium on the Mechanism of Phase Transformations in Metals

THE Metal Physics Committee of the Institute of Metals is proposing to hold in London a one-day symposium on "The Mechanism of Phase Transformations in Metals", at a date which will probably be in November, 1955. The symposium will be in two parts, the morning session being devoted to transformations which are largely governed by thermal activation (nucleation and growth reactions), and the afternoon session to transformations in which thermal activation is less important (martensitic reactions).

Review papers are being invited to introduce each session, but in addition the Committee will be glad to consider offers of short original contributions (up to 3,000 words) from workers in the field of phase transformations. In these contributions emphasis should be laid on the experimental results and their interpretation rather than on details of experimental technique. Anyone wishing to submit a short communication of this kind, is invited to send the title and a brief summary, as soon as possible, to the Editor, The Institute of Metals, 4 Grosvenor Gardens, London, S.W.1. The Committee will subsequently notify authors whose contributions it is proposed to include in either the morning or afternoon session, and final MSS. must be in the Editor's hands by 31st January, 1955.

Visits to Electric Furnace Works

DURING the winter, Wild-Barfield Electric Furnaces, Ltd., are pleased to welcome parties of up to 30 senior engineering students from technical colleges and members of technical societies to their Watford Works, where an interesting and extensive tour is arranged. The tour includes a visit to the production shops where electric furnaces from laboratory units to full scale production furnaces and induction heating equipment are to be seen in all stages of manufacture. The metallurgical and chemical laboratories provide opportunity for the study of research methods and equipment, whilst the development section affords the visitor scope for seeing many new heat-treatment processes and prototypes in the course of development.

An invitation is extended to parties of visitors from 1st September to May 31st, 1955, on a limited number of weekday afternoons (Monday to Friday) and early application is desirable as from past experience, dates get booked well in advance.

Practical X-ray Crystallography Course

A COURSE in practical X-ray crystallography will be held in the Physics Department of Battersea Polytechnic, commencing on Tuesday, 28th September, 1954. The course, which is intended for graduates and others suitably qualified who required practical experience in X-ray cyrstallography, will consist of lectures, demonstrations and practical work totalling about 54 hours. Aspects of the subject to be included are: the operation of gas and vacuum X-ray equipment; the use of standard X-ray cameras; single crystal, powder and back-reflection methods; and the interpretation of radiographs. Details may be obtained from the Head of the Department, and enrolment, for which the fee is £2 5s. 0d. should be made as soon as possible.

£2m. Order for G.E.C.

THE General Electric Co., Ltd., announces that it has undertaken as a comprehensive contract of over £2 million, the complete power station for the £20 million iron and steel project of Colvilles, Ltd., at Motherwell.

This contract includes the power house building and associated civil work; four Babcock & Wilcox gas and oil-fired boilers of 125,000 lb./hr. each; three 10-MW turbo-alternators with Mirrlees Watson condensing and feed heating plant, feed pumps and auxiliaries; and two steam turbo-driven centrifugal blowers of 11,000 h.p. each, for supplying air to the new furnaces. In addition, the work includes two ferro-concrete natural draught towers, each for cooling 1,200,000 gal/hr. of water; and two pumps driven by turbines arranged to exhaust steam to process plant; also the 11-kV switchgear for control of the alternators and feeders, L.T. switchgear and motors for auxiliaries, and the lighting installation.

Personal News

MR. M. E. DAVIES, who joined the British Iron and Steel Research Association in 1947, and created its public relations service, left at the end of July to become Editor of *Petroleum Times*.

MR. H. G. RAMSELL has been appointed General Manager of the British Lock and Hardware Division and the British Materials Handling Division of The Yale & Towne Manufacturing Company. He succeeds MR. J. R. WILDER who has been named Honorary General Manager of both Divisions.

BRITISH INSULATED CALLENDER'S CABLES LIMITED announce that MR. W. G. DUMVILLE, M.C., T.D., has been appointed Regional Manager, North East, to succeed MR. E. CHARLTON who is retiring. Mr. Dumville was formerly Assistant Sales Manager responsible for Wire Mill Products and Moulding Machines.

JENOLITE, LTD., have appointed MR. J. S. ARMSTRONG to be Marine Representative in their Technical Department. Mr. Armstrong was for eleven years a Chief Officer in the Merchant Navy and has had considerable experience of corrosion problems in shipping.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

New Low-Hydrogen Electrodes

A NEW and improved low-hydrogen welding electrode known as Fortrex 35 has recently been developed by Murex Welding Processes, Ltd., Waltham Cross, Herts. Features of this electrode are that it is easy to use in any position, it is smooth running, and the slag can easily be removed. It gives sound radiographs, even in positional welds.

Fortrex 35 has been specially designed to give deposits capable of resisting cracking under conditions of weld restraint, and it is particularly suitable for the welding of fabrications subjected to sub-zero temperature. the weld metal having a very low transition temperature. It can be used for the welding of plain carbon and low alloy steels normally outside the welding range, often without the need for preheating. Many of the difficulties associated with the welding of free cutting steels can be reduced by the use of this electrode.

The electrode is of the plain extruded type and is made in gauges Nos. 12–6, and in the $\frac{1}{4}$ in. and $\frac{5}{16}$ in. sizes. An ultimate tensile strength of 35–37 tons/sq.in. is obtainable on an all weld metal specimen to B.S. 639 : 1952, with an elongation of 30–35% and a reduction of area of 60–70%. The Izod impact at room temperature is 70–90 ft.lb., and at –20° C. 60–70 ft.lb. Fortrex 35 is approved by the Admiralty, Lloyd's Register of Shipping and the Ministry of Supply.

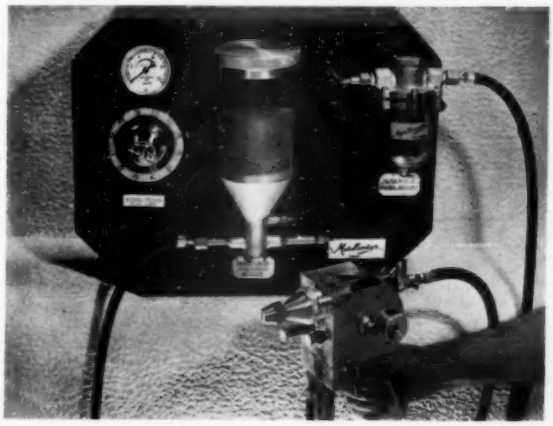
Murex Welding Processes, Ltd., Waltham Cross, Herts.

Spraywelding

As a result of extensive development work, Metallisation, Ltd., have now produced a valuable attachment for their Mark 16 metal spraying pistol. It comprises a powder container with transparent body ; an air filter ; a low pressure air regulator and gauge ; a complete nozzle with control tap ; and 15 ft. of powder feed tubing. With this equipment, it is possible to hardface components by a powder technique which is a combination of spraying and welding. The materials used are marketed under the trade name of Colmonoy, and the powder, which is a combination of nickel, chromium and boron, is available in three grades.

Because all " Sprayweld " deposits are heat treated and fused to the base material there is no objection to the use of powder, but, as the material is expensive, excessive losses during spraying are to be avoided. To meet this requirement, the attachment has been so designed that overspray is kept to a minimum by using a concentrated jet.

The Colmonoy alloys have a high resistance to oxidation at elevated temperatures and remarkable " wetting " properties. There is no sharp melting point, and on being heated to a certain degree the deposit becomes plastic within a range of about 100° C. It is during this range that the metal becomes plastic and bonds to the base metal. The temperatures concerned vary for the three grades, but are in the region of 1,000–1,100° C. One of the limitations of the process is size, as the part must be raised to the " fusing



point " of the alloys, and whilst this may be done in a furnace or by high frequency induction heating, individual jobs are best treated by multi-flame torch fusing.

The Colmonoy alloys can be made into welding rods, but the Spraywelding technique is claimed to have advantages over welding in respect of speed, economy of material, porosity and accuracy of dimensions. There is also less risk of distortion, and the smooth surface after Spraywelding facilitates grinding and reduces wear on the wheel.

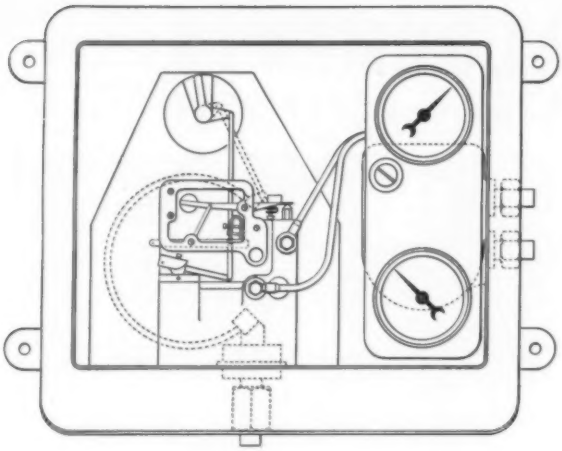
In the finished state the hardness values are subject to slight variation, but 550–600 Brinell may be regarded as average. The alloys used have a combination of corrosion and wear resistance which is extremely high, as illustrated by a pump spindle running in severely corrosive and abrasive conditions. The normal spindle, in stainless steel, had an average life of 14 days, but a mild steel Spraywelded component was still in service, with little wear apparent, after 11 months.

Metallisation, Ltd., Barclays Bank Chambers, Dudley, Worcs.

Pressure Transmitter

THE remote transmission of pressure (or suction) values has for some time been done electrically, but for safety and other reasons it is sometimes desirable to use a pneumatic transmission system in place of an electrical one. George Kent, Ltd. announce the addition to their comprehensive range of instruments of an air-operated pressure transmitter to meet these circumstances.

This instrument is purely a transmitter ; it does not include any recording or indicating mechanisms. Any normal pressure or suction value can be measured and is converted to an air signal which bears a linear relationship to the measured value. This air signal is fed to a receiving instrument which continuously indicates or records the measured value. A convenient site can be chosen for the equipment in the plant, and once the initial setting has been carried out the transmitter requires almost no attention.



Two types of measuring element can be fitted in the instrument. For pressure ranges of 0–15 to 0–2,000 lb./sq.in., a Bourdon tube is employed; while for suction values, and pressure ranges of 0–3 to 0–14 lb./sq.in., bellows units are used. The measuring element is connected by means of a suitable linkage to a Kent Mark 24 transmitter, which generates the air signal for transmission to the receiving instrument. Both the measuring element and the Mark 24 transmitter are assembled on one plate fitted in the left-hand side of the instrument case. The transmitter operates on the normal air-supply pressure of 17 lb./sq.in., and this is taken from the main air supply *via* a filter and a combined relay/pressure reducer. These are located behind the "supply" and "transmission" gauges in the right-hand side of the case. The supply pressure can be set by hand, but is usually set at 17 lb./sq.in., and locked in that position. All parts are readily accessible. For gas-pressure measurement the instrument is usually mounted above the tapping point, to allow moisture to drain back into the main.

George Kent, Ltd., Luton.

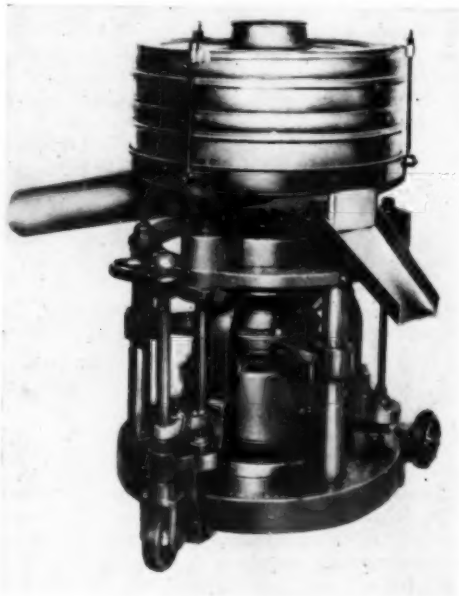
New Screening Unit

One of the most interesting and notable advances made in recent years in the processing of fine materials is the progress made in sieving and straining technique, and Russell Constructions, Ltd., well-known experts in this field have now placed on the market their new Cascade unit, a machine which is unique in that it combines the high capacity and non-blinding properties associated with the gyratory screen principle with the automatic and continuous rejection of oversize material.

The machine consists of three superimposed circular screens vibrating with a gyratory motion, which causes the particles of the material to be sieved to radiate outwards in a curved path. On coming in contact with the first screen a certain amount of the fine particles passes through it and goes down a central tube to the discharge outlet. The remainder of the material passes over the edge of the screen and falling on to the sloping surface of the transfer funnel is directed to the centre of the second screen. More of the fine particles pass through this screen to the outlet while the coarser material travels over the edge to the centre of the bottom screen. By the time the material has reached the outer edge of this screen all the finer particles have been separated and the coarse material remaining passes off through a gutter to the reject outlet, which is on the opposite side to the main discharge outlet.

An outstanding feature of the "Cascade" is the complete absence of clogging and blinding of the mesh when in operation. The gyratory movement of the screen imparts a rolling motion to the particles of the material being sieved, thus eliminating the bouncing action which by hammering the larger particles into the mesh causes blinding of the screen.

The machine is powered by a $\frac{3}{4}$ h.p. electric motor and can be supplied mounted on a mobile stand, or suspended from the ceiling for use where material is stored in an upper storey of a building and fed by gravity through an aperture to the lower parts of the establishment. The gyratory unit is accurately balanced so that no vibration is transferred to the static part of the machine. The sieving assembly is contained in a dustproof housing 22 in. in diameter and $10\frac{1}{2}$ in. high, and can easily be dismantled in a matter of minutes for re-meshing if necessary. The total area of the screening element is $6\frac{1}{2}$ sq. ft., and the best results are obtained when using textile meshes such as nylon.



There are certain types of metallic or plastic powders, whose particles assume an elongated wedge shape. These products, on account of their tendency to become wedged in the mesh apertures have always proved difficult, and sometimes even impractical, for sieving purposes, but when processing such materials on this machine, even after prolonged runs of many hours, it is claimed that the mesh surface always remains perfectly clean.

Russell Construction, Ltd., 8, *Adam Street, London, W.C.*2.

CURRENT LITERATURE

Book Notices

S.S. *OCEAN VULCAN* STATIC EXPERIMENTS

Report No. R.6 of the Admiralty Ship Welding Committee. 50 pp. (including numerous illustrations), 8 tables and 109 diagrams (full page or larger). 1953, London, H.M. Stationery Office. 30s. net.

THIS report describes an investigation of the stress response of the welded cargo ship S.S. *Ocean Vulcan* under various conditions of loading in still water. These conditions, which were obtained by flooding ballast tanks and holds, were so arranged that they could be directly related to the various actions to which a ship is subjected at sea.

The preparations of the ship for the experiments and the conditions existing at the anchorage are described, and details of the various loading conditions and methods of calculating moments of inertia and bending moments are given in separate tables. The results are presented in diagrammatic form, accompanied by a brief description in the text. Particular attention has been paid to the changes in stresses near amidships due to the changes in loading of certain panels of plating, and to the stress distribution at structural details.

An historical survey of previous experiments carried out on ships under static loading is given in an Appendix.

S.S. *CLAN ALPINE* STATIC EXPERIMENTS

Report No. R.7 of the Admiralty Ship Welding Committee. 16 pp., 16 plates, 9 tables and 116 diagrams (full page or larger). 1953, London, H.M. Stationery Office. 30s. net.

THIS report describes a similar investigation to that reported in R.6, but in this case the vessel, S.S. *Clan Alpine* is a riveted cargo ship.

S.S. *OCEAN VULCAN* SEA TRIALS

Report No. R.10 of the Admiralty Ship Welding Committee. 13 pp., 187 diagrams (full page or larger). 1953, London, H.M. Stationery Office. 42s. net.

Report No. R.11 of the Admiralty Ship Welding Committee. 12 pp., 124 diagrams (full page or larger). 1954, London, H.M. Stationery Office. 37s. 6d. net.

THESE two volumes, which should be read in conjunction with Report No. R.8, wherein the nature of the trials is fully described, give the detailed analyses of two of the more important records taken during the sea trials of the welded cargo ship S.S. *Ocean Vulcan*. The trials were conducted as part of a more general investigation of the relative behaviour of welded and riveted ships. Report No. R.10 refers to Record No. 6.E.7 (loaded condition) and Report No. R.11 to Record No. 6.W.5 (ballast condition). The latter was made when the ship was navigating at reduced speed in head seas, and slamming occasionally occurred.

In both reports the general conditions of the ship's loading and of the seaway at the time are given, together with extracts from the field data, with a brief discussion of their significance. Some of the more interesting cases selected from the detailed analysis are published in full in order to show the magnitudes of the accelerations and bending moments, the variations in hydrostatic pressure, and other actions along the length of the ship. An estimate of the probable accuracy of the results is made. Envelope curves are given to show the maximum values of bending moment, etc., which were recorded along the length of the ship, and an investigation has been made to ascertain the combinations of the various actions which cause the highest stress amidships.

Trade Publications

IN the July issue of *B.T.L. Bulletin and Laboratory Notes*, published by Baird & Tatlock (London), Ltd., details are given of the B.T.L. Universal Kjeldahl apparatus, new designs of laboratory stirrers, oil testing equipment, laboratory ovens, and a number of miscellaneous items of laboratory equipment. This is the first of a new series of the *Bulletin*, which had been discontinued during the production of an entirely new range of catalogues now available to those interested. The new B.T.L. Catalogue is issued in alternative forms, namely: (*a*) General Instruments, Apparatus and the Medical Sciences; (*b*) General Instruments, Apparatus and the Industrial Sciences; (*c*) General Instruments, Apparatus, Medical and Industrial Sciences. The Hopkin and Williams Catalogue has also been published in a much more comprehensive form. It contains over 300 additional items and four entirely new sections: "Polaritan" Reagents for Polarographic Analysis; Reagents for the Determination of Lead in Foodstuffs; Bacteriological Sugars and Related Substances; and Silanes and Organo-Silicon Products. There is also an interesting account of British Reagent Specifications, copious cross references and notes on certain chemicals whose names do not clearly indicate their constitution.

THE Metals Division of Imperial Chemical Industries, Ltd., has long specialised in the fabrication of copper, brass and aluminium to customer's requirements. In some instances only blanking or cupping is needed, in others, processing may continue to the point where only polishing or plating is required to finish the article. By using such partly processed products, the customer is relieved of labour and transport charges incidental to the handling and disposal of webbing scrap. In a recently issued brochure, typical fabricated products shown include fire extinguisher bodies, coins and coin blanks, pen and pencil parts, radiator tubes, medical accessories, cosmetic and toilet accessories, petrol lighter parts, cycle components, cups and blanks, and miscellaneous pressings for the electrical, automobile and other industries.

WE have received from Londex, Ltd., a number of new leaflets describing various products of the company. List 94/F deals with the Lectralevel liquid level control system. No float is used in this device, control being effected by the passage of a current through the liquid. Two electrodes are immersed in the liquid to different depths. The relay is energised with the liquid reaches the shorter electrode, and operation is maintained by the small current through a shunting resistor until the level falls below the lower electrode. As alternating current is used, there is no electrolysis. For non-conducting liquids, reference is made to a mercury float switch device, and for high pressure and dangerous liquids, there

is a float inductor system. The remaining leaflets deal with a Type LQA triple pole 60 amp. heavy duty mercury switch relay contactor (List 159) ; control unit for small generating sets (List 160) ; and a new portable flashing obstruction light (List 161).

THE health hazards associated with grinding are well-known and reference has been made from time to time to efforts being made, particularly by the research associations, to deal with dust arising in this and other industrial dust raising processes. In a leaflet (E.535) issued recently, Air Control Installations, Ltd., describe their Dusgard, which can be attached to the exhaust system of a pedestal grinder. It employs a technique developed by the British Cast Iron Research Association, known as external dust control, in which the essential feature is the use of currents of fast-moving air to form an invisible curtain or dustguard to contain and collect the very small dust particles which, although invisible to the naked eye, are highly dangerous to the lung tissue.

ALUMINIUM alloys in the form of plate, sheet, strip, tubes and extrusions, conforming with British Standard, Lloyds, Admiralty and other specifications, are featured in a new brochure issued by T.I. Aluminium, Ltd. Although some of the alloys can best be described as special purpose, the majority of users requirements can be met by one or other of the commercial alloys manufactured in bulk, thus ensuring minimum cost and early delivery. Before presenting the detailed properties of each alloy, the brochure summarises them into alloy types, depending on the alloying elements used, and details the nomenclature used in describing the alloys and their heat treatment.

THREE types of refractory brick are dealt with in three new leaflets issued by the Refractories Group of the Morgan Crucible Co., Ltd. The M.R.1, described in leaflet RD42 can be used at temperatures as high as 1,600° C. This is claimed to be higher than applies with other refractories of similar alumina content, due to the control exercised in manufacture. RD43 deals with the M.I.28 hot-face low heat-storage insulating refractory which can be used at furnace (or interface) temperatures of 1,540° C. An important feature of the M.I.28 is the low heat-storage capacity, which is very useful on batch furnaces as it allows of more rapid heating up. The M.I.23 (RD44) can be used as a direct furnace lining up to 1,260° C., where furnace conditions are clean, and, where temperatures are higher, it can be used as a backing insulation to a lining of denser refractory or of another hot-face refractory such as M.I.28.

" BERYLLIUM NICKEL " is the title of a new publication by The Beryllium Corporation, Reading, Pennsylvania for whom the agents in this country are Beryllium Smelting Co., Ltd. Beryllium nickel is used for castings where corrosion resistance of the type normally expected of a high nickel material is required. There are two principal alloys : CR-1, with a nominal 2·75% beryllium and carbon 0·5% max. ; and CR-2, with a higher carbon content (0·75–1·10%), which is easier to machine than CR-1. These alloys may be heat treated to give a tensile strength of 85–90 tons/sq. in. The fluidity of molten beryllium nickel has led to its use in small, detailed investment castings.

THE Incandescent Heat Company's leaflet V.27 deals with the Type 2,000° C. furnace, which incorporates alternating flow intensive heat recovery to a degree which results in extraordinary high efficiency, reliability and thermal response. It was developed to meet the demand for a practical research and production unit suitable for operating at temperatures up to 2,000° C. In the Temgas muffle-type of furnace described in V.29, temperatures up to 1,450° can be rapidly attained and maintained at high efficiency by natural draught. This unit is manufactured under licence from the North Thames Gas Board. Incandescent have also available a reprint describing the 500 cu. ft./hr. nitrogen generator. Town's gas is burnt with the correct amount of air for full combustion and the other gases removed by cooling and absorption.

IN a foreword to " All in a Day's Work at Accles and Pollock," reference is made to the difficulty of trying to compress into a 32-page booklet the quintessence of Accles and Pollock's tube making, as at least seven full-sized books are published dealing with this, that and the other of their specialised activities. The present publication does, however, give an indication of the applications of Accles and Pollock products on land, at sea, and in the air, and in the home, in industry and in sport. Moreover, it is extensively illustrated and the story is told in both English and French.

NEW METALS AND CHEMICALS, LTD., have recently published a list of their products, which include the rare metals and their compounds—oxides, ores, alloys and salts —and quartz and vacuum equipment. The quartz products comprise tubes, rods, and shapes, thermocouple sheaths, infra-red driers, etc., whilst coating plants, pumps, sintering plant and arc-melting furnaces, etc., are featured in the vacuum plant equipment.

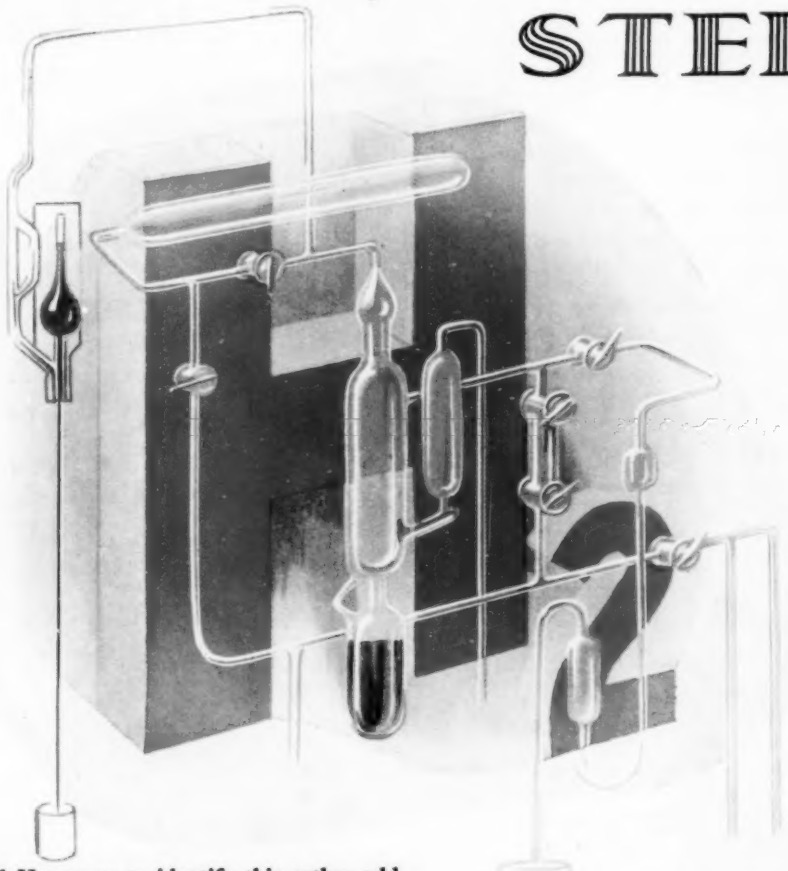
THE Aluminium Development Association's Directory of Members gives the names of the Members of the Council, a brief statement of the constitution and objects of the Association and the names, addresses and other particulars of its member companies, including where applicable associate or subsidiary companies. In each case a short description is given of the activities and products of the company. By means of an index of products classified under Aluminium and Aluminium Alloys, readers are referred to all member companies producing any particular products.

THE latest data sheet issued by Alar, Ltd., concerns a new alloy ALAR 21, which is virtually identical with LM.4 in all its properties and characteristics. The introduction of the new alloy does not, therefore, provide the users of aluminium castings with a new material of unknown behaviour, but it has the particular merit that its composition allows the ingot manufacturers to make a more efficient use of available raw materials, and so ensures that the demand of the foundries and users for a good general purpose alloy may continue to benefit.

" THE APPLICATION OF LIGHT ALLOYS TO ENGINEERING," a publication of Head Wrightson Aluminium, Ltd., has a novel front cover, which takes the form of a sheet of impressed aluminium supplied by the British Aluminium Co., Ltd. The Company is a subsidiary of Head, Wrightson & Co., Ltd., and was formed in 1946, to undertake the development and fabrication of aluminium alloys. Following a discussion of the considerations involved in the use of aluminium alloys in structural engineering, examples are given of notable contracts carried out by the Company. They include bridges with movable elements, long span overhead cranes, crane jibs, hangars and hangar doors, building structures, wind tunnels, mine cages, dragline buckets, etc.

Formula for

STEEL



The Symbol H_2 serves to identify this rather odd arrangement of glass vessels and tubing as the equipment used to estimate the hydrogen given off by a heated specimen of steel.

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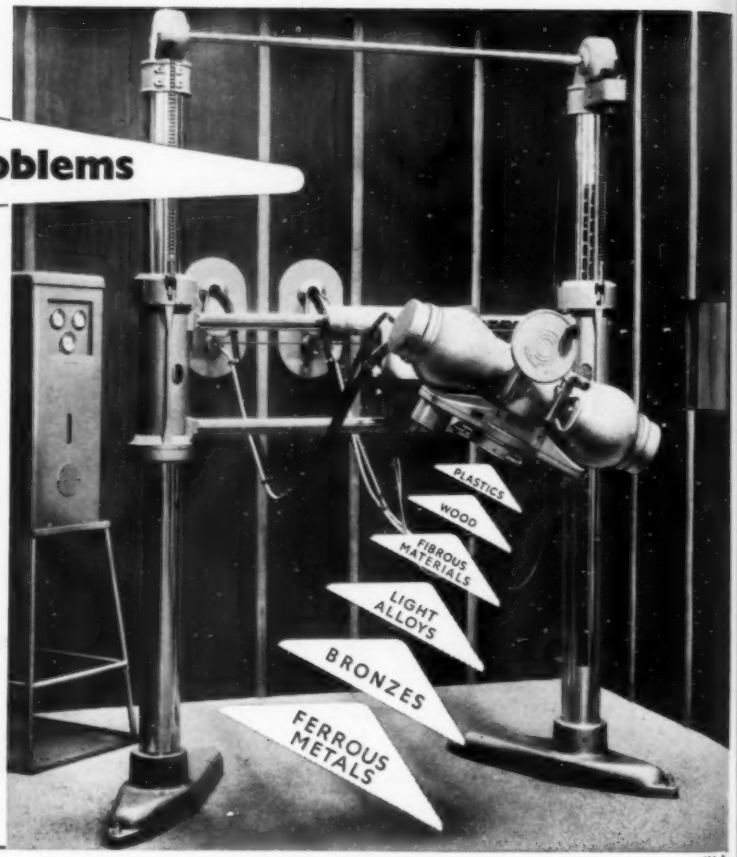

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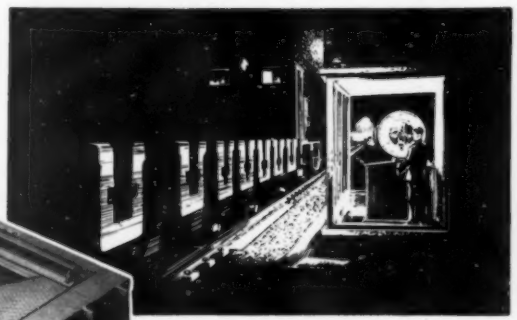

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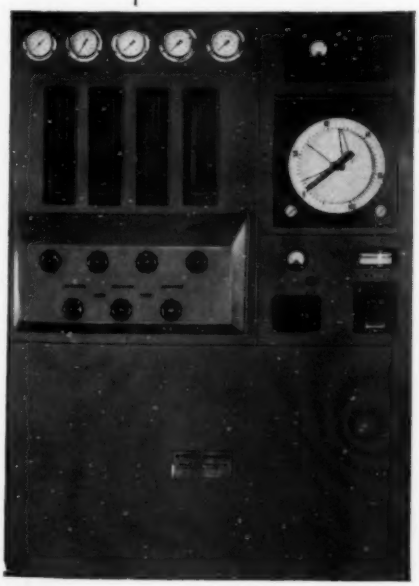

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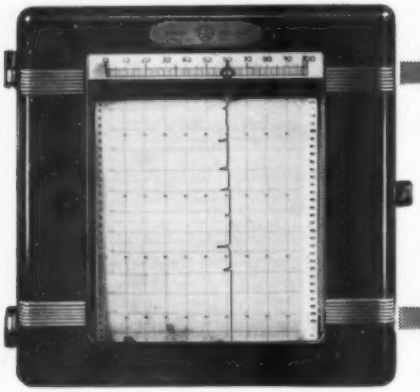

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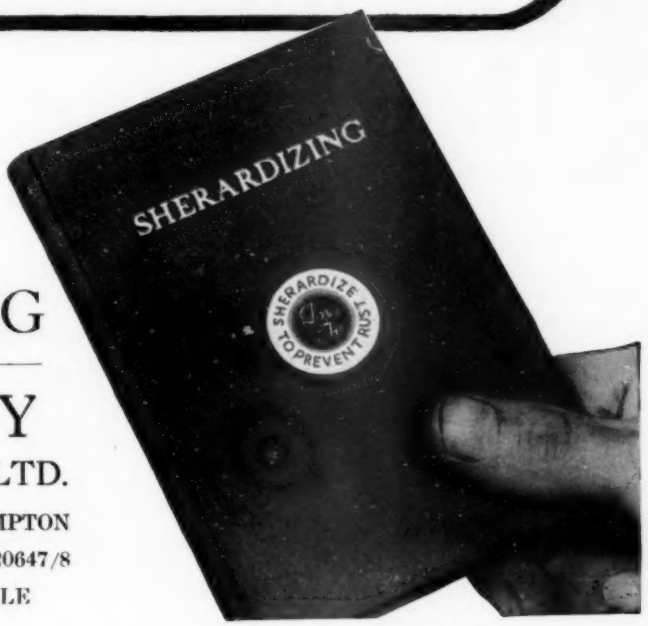

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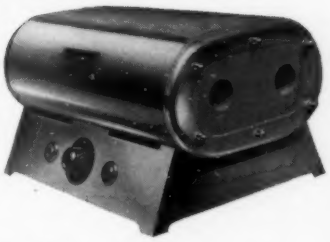

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AUGUST, 1954 Vol. L, No. 298

A Simple Anodising Process for Revealing the Grain Structure of Aluminium Alloys

By H. G. Cole and W. J. D. Brooks
Metallurgy Department, Royal Aircraft Establishment

The grain structure of a wide range of aluminium base materials in rolled, extruded and cast form, can be observed under polarised light after the metal surface has been anodised at 2·5 amp./sq. dm. in a 50% aqueous solution of phosphoric acid. Best results are obtained if the process is carried out in the region of 0° C.

THE deposition of anodic films on aluminium to reveal the grain structure under polarised light has been described by Lacombe and Beaujard[1] and by Hone and Pearson.[2] Lacombe and Beaujard used a 10% sulphuric acid solution in which the specimen was anodised at 1·5 amp./sq. dm. for 30 minutes at 15° C.; they confined their attention to superpure aluminium. Hone and Pearson used a solution containing 70% orthophosphoric acid (85%), 26·5% Carbitol, 2·5% water, and 1% hydrofluoric acid, in which the specimen was anodised at approximately 1·6 amp./sq. dm. for 20 minutes at room temperature, and confined their attention to pure and superpure aluminium.

On attempting to use these methods on alloys of aluminium, it was found that the first bath behaved erratically and was difficult to control, and the second bath tended to attack and pit the alloys.

Preliminary experiments showed that anodising at a low current density in 50% aqueous phosphoric acid solution gave suitable films on a wide range of aluminium-rich materials in various states of heat treatment, and it was decided to investigate this solution in detail. The solution had been used earlier at greater current density and higher temperature (15 amp./sq. dm. at 30–40° C.) by Forsyth[3] for the electropolishing of aluminium—½% silver alloy.

Variations in Anodic Treatment

Specimens were prepared for anodising by electropolishing them in the standard Disa Electropol in a flowing solution made up from 350 ml. absolute ethyl alcohol, 50 ml. perchloric acid (S.G. 1·54), 50 ml. glycerol and 50 ml. distilled water. They were then anodised for periods from 20 seconds to 2 minutes until a film was obtained which showed a large variation in shade from grain to grain when viewed under polarised light. Most of the experiments were made with a platinum cathode, but no change in behaviour was noticed when platinum was replaced by aluminium.

(i) *Current Density*—A current density of 2·5 amp./sq. dm. was found to give the best results. At higher currents, polishing occurred without deposition of film, and at lower currents, film deposition was slow and some chemical attack and pitting occurred.

Fig. 1.—Superpurity aluminium sheet, as cold rolled from forged billet, showing extreme deformation. × 100

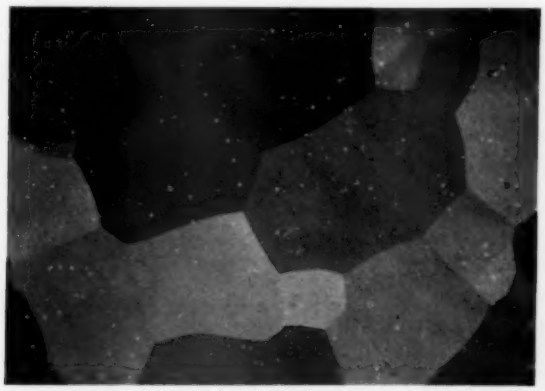

Fig. 2.—Superpurity aluminium sheet cold rolled from forged billet and annealed for 1 hour in nitrogen at 600° C. × 100

Fig. 3.—Superpurity aluminium —5% zinc alloy sheet annealed for 1 hour at 460° C. × 150

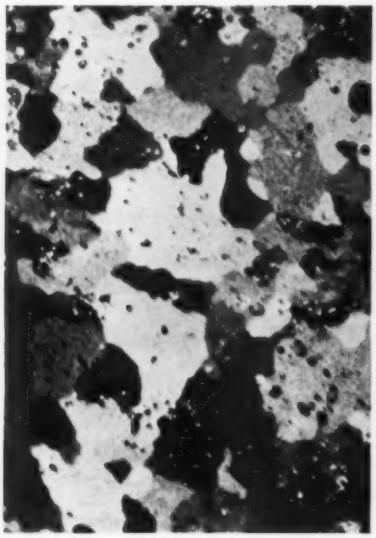

Fig. 4.—D.T.D.603 sheet, as supplied. × 240

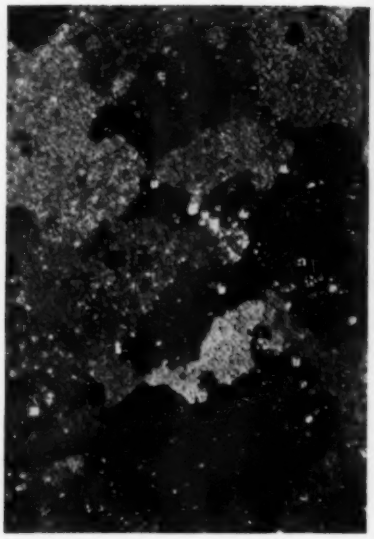

Fig. 5.—D.T.D.646 sheet, as supplied. × 240

(ii) *Concentration and Temperature*—Five solutions containing, respectively, 25, 40, 50, 60 and 75 ml. phosphoric acid (S.G. 1·75, 90% H_3PO_4) made up to 100 ml. solution with distilled water were prepared, and specimens of various compositions anodised in them. Table I shows the quality of the anodic film and the voltage required to maintain an anodic current density of 2·5 amp./sq. dm.

The best results were obtained with the 50% solution at low temperature, and in use, the solution should be stirred to prevent local rise in temperature. A bath consisting of 50 ml. melted 100% phosphoric acid made up to 100 ml. with absolute alcohol also gave good results at room temperature and a voltage of 30 , but showed no advantage over the aqueous solution.

Application to Various Alloys

The materials listed in Table II were anodised successfully in the 50% aqueous phosphoric acid bath at 20° C. with a current density of 2·5 amp./sq. dm. and a voltage of 40 volts unless otherwise stated. The photographs of the specimens illustrated in Fig. 1 to 11 were taken between crossed polaroid screens on a Vickers projection microscope illuminated with a 250-watt mercury vapour lamp at maximum aperture. The period of exposure for Chromatic plates was 25 to 35 seconds. For the wrought specimens, the planes illustrated lie in the direction of rolling and extrusion respectively.

TABLE I.—EFFECT OF CONCENTRATION AND TEMPERATURE.

Temperature of solution	Concentration of phosphoric acid				
	25%	40%	50%	60%	70%
—5° C.	Fair 75v	Fair 55v	V. good 50v	Good 55v	Fair 70v
20° C.	Fair 55v		Good 40v	Fair 30v	Polished, no anodising 30v
50° C.	Attack and pitting 9v		Attack and pitting		

TABLE II.—MATERIALS SUCCESSFULLY EXAMINED BY THE ANODIC PROCESS.

Material	Condition	Duration of Anodising (seconds)	Illustrated in Figure
Sheet			
Superpure aluminium	As cold rolled from forged billet	60	1
	Cold rolled material annealed for 1 hour in nitrogen at 600° C.	40	2
Commercially pure aluminium—L16	Half hard material.	20	
	Half hard material annealed for 1 hour in nitrogen at 600° C.	20	
	Half hard material annealed and reduced 50% by cold rolling	20	
	Half hard material annealed, reduced 50% by cold rolling and annealed for 30 minutes at 150° C.	120	
Superpure aluminium —5% magnesium alloy	Heavily cold rolled from cast billet	120*	
Superpure aluminium —5% zinc alloy	Annealed for 1 hour at 460° C.	120	3
D.T.D. 180B (Mg 3·5%)	As supplied	40†	
D.T.D. 603 (Cu 4·4% Mg 0·7%, Si 0·7%, Mn 0·6%)	Solution heat treated—as supplied	90	4
D.T.D. 646 (as D.T.D. 603)	Fully heat treated	90	5
D.T.D. 687 (Zn 5·5%, Mg 2%, Cu 1·25%)	Fully heat treated—cladding removed	100	6
Extrusions			
Commercially pure aluminium—L34	As supplied	60	
Superpure aluminium —5% magnesium alloy	As extruded	20*	7
Superpure aluminium —4% copper alloy	As extruded	90	
D.T.D. 364 (Cu 4%, Mg 0·5%, Si 1%)	As supplied	60	
D.T.D. 683 (Zn 5·5%, Mg 2·5%, Cu 1%)	As supplied	10	8
Castings			
D.T.D. 165 (Mg 4·5%, Mn 0·5%)	As cast	60	9
Superpure aluminium —5% copper alloy	As cast	60	10
L11 (Cu 7%)	As cast	60	
D.T.D. 304 (Cu 4·5%, Ti 0·2%)	Fully heat treated	100	11

* At 5 amp./sq. dm., 50 volts.
† At –5° C., 50 volts.

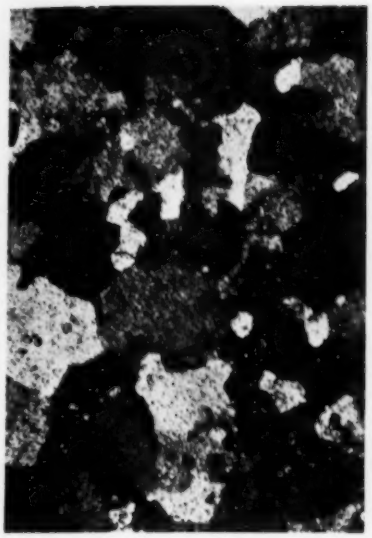

Fig. 6.—D.T.D.687 sheet, as supplied (cladding removed). × 240

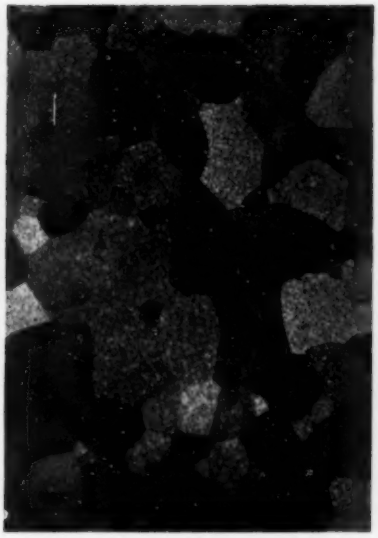

Fig. 7.—Superpurity aluminium —5% magnesium alloys, as extruded. × 150

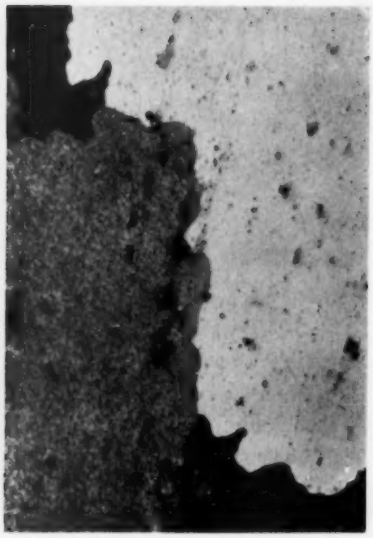

Fig. 8.—D.T.D.683 extrusion, as supplied. × 150

Clear contrast between neighbouring grains was shown by superpure aluminium, and by superpure alloys with copper, zinc and magnesium. In commercial purity materials, especially those containing a high proportion of alloying elements, spots and smudges in the anodic film reduced the contrast. Alloys containing magnesium from 3% upwards were the most difficult to anodise; a low temperature or higher current density was essential for the production of films giving good contrast. The method failed with the cast aluminium—12% silicon alloy, in which eutectic was widespread, and with the cast aluminium—10% magnesium alloy (L.53).

Examination under Polarised Light

The grain boundaries of some of the anodised specimens were just visible by normal light. When the specimens were illuminated through a polarising screen and viewed through a second polarising screen set at right angles to the first, the various grains had shades varying from light to dark. When the specimen stage was rotated, two types of change of shade were observed,

	0°	45°	90°	135°	180°
Type I	white	black	a colour	black	white
Type II	light		dark		light

Fig. 9.—D.T.D.165, as cast, showing intermetallic compound at boundaries and within grains. × 150

Fig. 10.—Superpurity aluminium —5% copper, as cast, showing eutectic network throughout grains. × 100

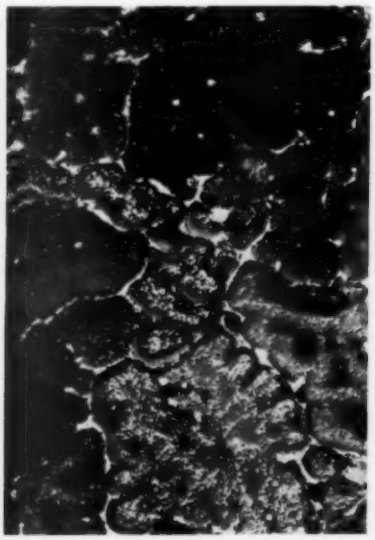

Fig. 11.—D.T.D.304 casting, heat treated. × 150

In Type I, the colour was orange or blue or green. Type II varied from a black to white change, through a pinkish black to greenish white, to a full pink to green change. Many of the materials showed grains of both types adjacent.

Mott and Haines[4] and Perryman[5] have reviewed the literature on the examination of metals under polarised light. When a cubic metal such as aluminium is examined under crossed polarising screens, the intensity of all grains is zero if the illumination of the surface is vertical, as it is in a metallurgical microscope. If, however, an anisotropic film is deposited on the surface, such that the thickness or orientation or surface contour depends on the orientation of the underlying metal grains, then the grains will reflect a plain polarised beam at normal incidence with varying degrees of ellipticity, and under crossed polarisers will appear to be of different shades. The colour effects apparently arise from differences of absorption or reflection of different wavelengths by the film.

Colour effects of a different kind were observed whenever one particular spare polaroid screen was used. With this screen, whether used as polariser or analyser, all the grains were of a red colour, varying from dark red to light pink. The reason for this effect was probably that the screen was of an old type which transmits red light even when crossed with a nicol prism.[6]

Conclusions

A simple anodic process has been investigated which reveals the grain structure of a wide range of aluminium base materials examined under polarised light. The process consists of anodising in a 50% phosphoric acid solution at a current density of 2·5 amp./sq. dm. The temperature should not be allowed to rise above room temperature, and should preferably be kept in the region of 0° C.

Acknowledgments

The authors thank Mr. P. J. Forsyth and Mr. J. C. Terry for advice and assistance. Acknowledgment is made to the Chief Scientist, Ministry of Supply, for permission to publish this paper. Crown Copyright reserved. Published with the permission of the Controller, H.M. Stationery Office.

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Exhibits of Metallurgical Interest at the Physical Society Exhibition

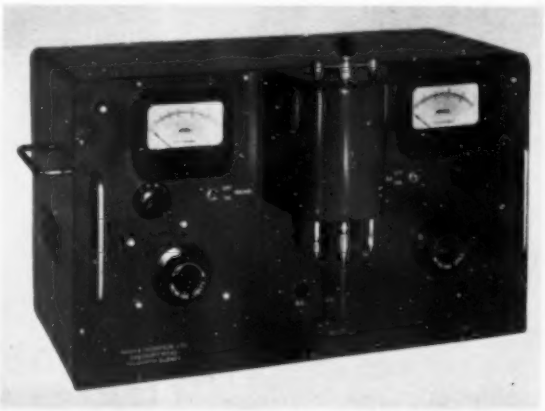
The exhibits at the Physical Society's annual exhibition of scientific instruments usually include a number of interest to workers in the metallurgical field. This year was no exception and in this issue we continue a short series of reviews in which such items will be described.

Electrolytic Polishing Equipment

THE standard method of preparing metallurgical specimens for examination is to mount them in a plastic mould (usually bakelite) and then polish with successively finer grades of abrasive paper. Finally the specimen is polished on a wheel with a very fine grade of alumina. The disadvantage of this procedure is that, unless great care is taken in the final stages, the true structure of the metal will be disguised by distortion and spreading of the surface layers. The acid etching which normally follows the polishing operation will then reveal the structure of the distorted layer, and not that of the underlying layers, and thus a false impression may be received.

To overcome this difficulty, the operation of electrolytic polishing was devised, largely by P. Jacquet and his co-workers in France. Briefly, the specimen to be polished is made the anode in a solution which is specific for each type of metal. The distorted surface layer is removed by electrolysis, and the specimen is left with a much higher polish than previously. In addition, it is the true structure of the metal which is revealed by subsequent etching.

With the increasing use which is being made of metallurgical techniques, there is a need for a suitable laboratory instrument with which to polish metallurgical specimens. The Nash & Thompson Electrolytic Polisher has been developed to meet this need. At present there is no other equipment of this type manufactured in this country.



Nash and Thompson electrolytic polishing equipment.

The polisher is housed in a large rectangular box and all the necessary fittings and controls are mounted on the front panel. In the middle of the panel, and toward the top, is the mounting for the electrodes and the stirrer. These are arranged so that they may be lifted (and locked in the raised position) to facilitate the removal of the beaker in which the specimen is polished.

The working range of the instrument is 0·70 volts with a maximum current of 5 amps. Care has been taken to smooth the current throughly as good polishing requires very steady conditions. Both current and voltage are indicated by flush-mounted meters, and control is effected by a variable auto-transformer. The stirrer has variable speed control.

Cathodes are made of different materials for the different solutions and a range is available in copper, aluminium and stainless steel. A glass cooling coil is also provided as some solutions need a high current which generates considerable heat.

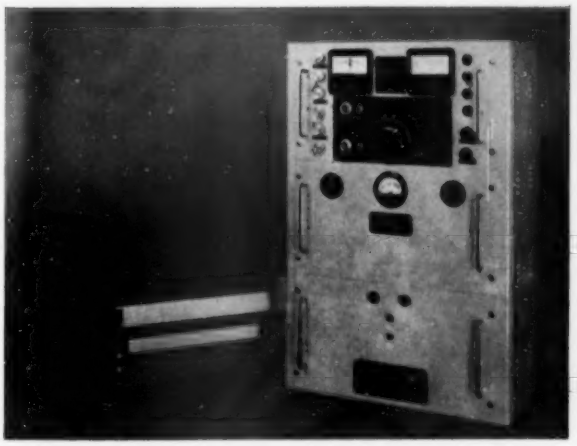
The chief advantage claimed for this instrument when compared with imported polishers is its adaptability to a variety of different sized specimens, and to the ease with which different metals can be polished (i.e. merely by changing the beaker and the cathode).

Radioactive Thickness Gauge

When beta radiation, consisting of fast electrons from a radioactive source, is directed at a sheet of paper, metal or other material, part of the radiation is reflected or scattered, another part is absorbed, and, up to some limit set by the weight per unit area and atomic number, beyond which total absorption takes place, the remainder emerges on the other side of the sheet. The transmitted radiation can be arranged to fall on a detector placed opposite the radioactive source, on the other side of the sheet, and the ionisation current derived from the detector, after appropriate amplification, serves to indicate the weight per unit area of the sheet.

The effect depends intrinsically on mass or weight per unit area and metals having different densities, or appreciably different atomic numbers thus have different calibration curves for the determination of thickness. Small variations in composition, such as may occur from cast to cast in the same alloy have a negligible effect. For instance, the calibration for 80 : 20 brass differs by only 1% from that for 70 : 30 brass. For thin foils of low density metals, a soft radiation of low penetrating power is used so that an appreciable portion of the radiation is absorbed by the foil. For thick sheets of high density metals, on the other hand, a hard penetrating radiation is required, an appreciable portion of which is transmitted by the strip.

The "Atomat" beta ray thickness gauge made by Baldwin Instrument Co., Ltd., is available for use in rolling mills, the deviation from the correct thickness figure being shown on a calibrated dial, the sensitivity being adjusted so that full scale corresponds to 1½–2 times the working tolerance. The operator can then estimate the changes necessary to correct a deviation. Standard models are available for use with aluminium foil, and light, medium and heavy aluminium strip, the source for the first two being Thallium 204, for the third Strontium 90 and for the heavy strip Cerium 144. Models for foil and light and medium strip in steel and copper alloys use the same three sources. A special



Atomat beta ray thickness gauge with the measuring head on the left.

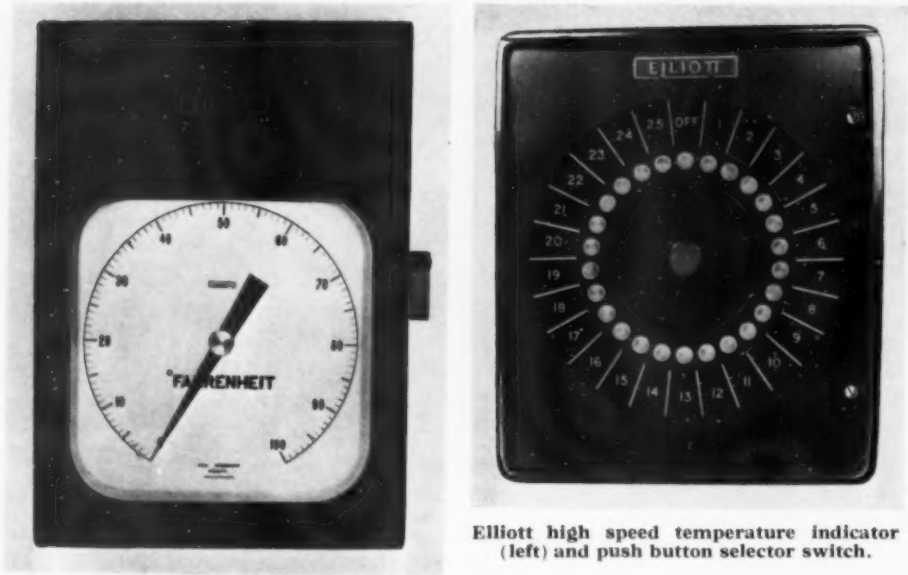
model for inspecting and grading sheets can be extended for automatic operations. For use with very light materials is a special head which effectively compensates for variations in the density of the air in the measuring gap.

Miniature Photomicrographic Camera

The Beck 35 mm. photomicrographic camera is designed to fit over the eyepiece of the Beck monocular microscope or, by adaption, to any other standard microscope. The size of the picture is 1 in. diameter, and the camera accommodates sufficient 35 mm. perforated film for 40 exposures.

The observing system is designed so that the operator can set up and adjust the instrument, carry out a search on the specimen, and at any time take a photograph, observations being made up to, and during, exposure. It has a reflecting and beam-splitting device at the

Beck miniature photomicrographic camera.



Elliott high speed temperature indicator (left) and push button selector switch.

junction of the vertical and inclined tubes, which directs an image of the object into the observing tube, in which is an accurately located crossline set parfocal with the film plane of the camera. An achromatic magnifier of 2 in. focus is used to observe the image, which is focused until it is coincident with the crossline. The magnifier can be focused relative to the crossline to suit the eye of the individual operator. The light transmitted to the camera constitutes 80% of the incident light : this ratio has been selected as the best balance of light intensities received by the eye and the camera, making the use of neutral filters for observing unnecessary.

For loading and unloading purposes, the complete camera is removed and taken to the dark room. The winding sprocket has a click device to locate each picture, and one complete turn of the wind-on knob moves the film forward one picture. A counter is provided to indicate the number of the picture in position. An eight speed shutter is fitted, giving exposures of 1/250th, 1/100th, 1/50th, 1/25th, 1/10th, 1/5th, $\frac{1}{2}$ and 1 second bulb and time. This is operated by an antinous release.

High Speed Temperature Indicator

The Elliott high speed temperature indicator has been developed for use in temperature measurement applications where repeated response to temperature changes is of importance. It is particularly applicable in multi-point installations where many variables need to be logged at a central control station with the aid of a single instrument and switch.

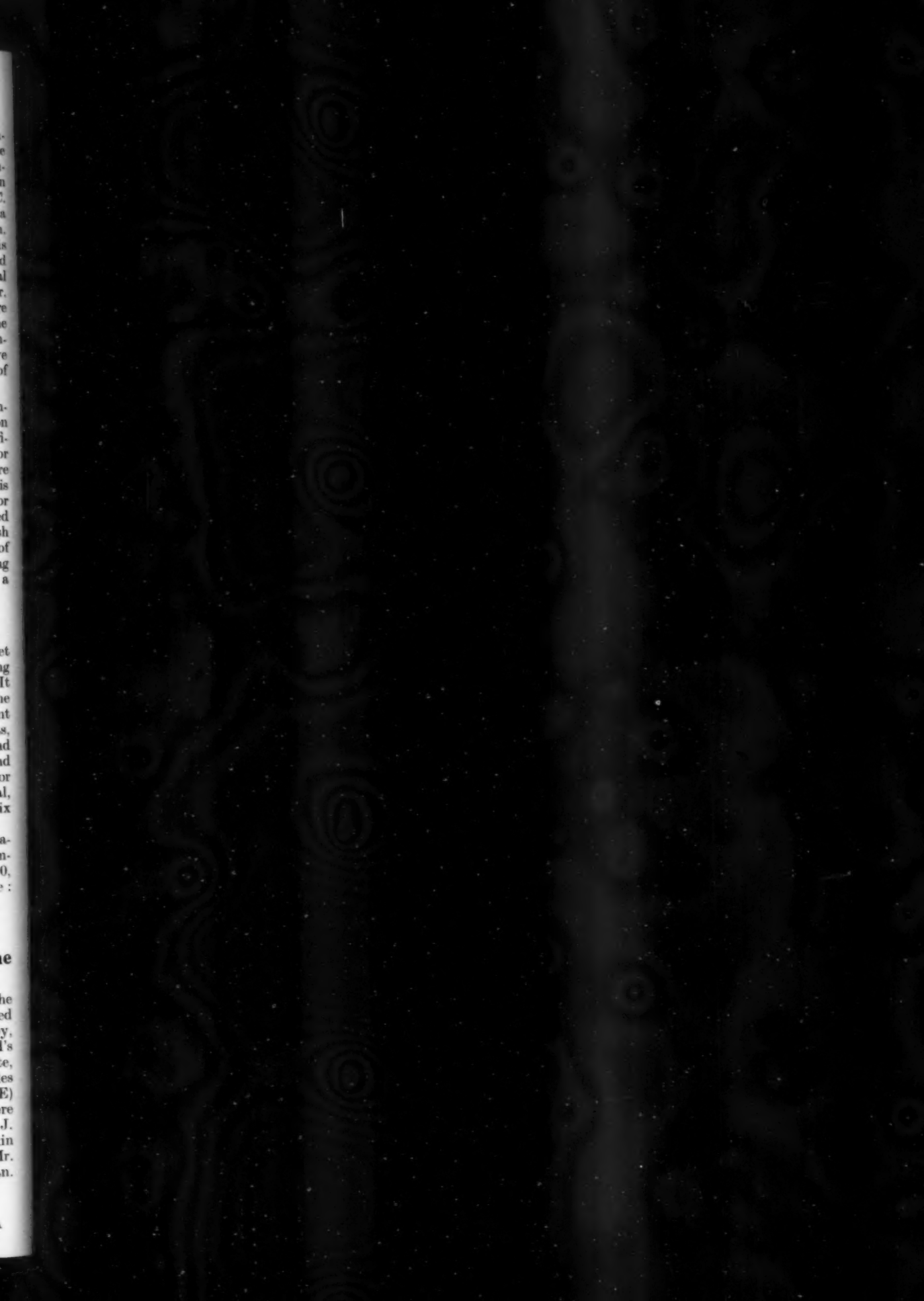
Temperatures which can be reproduced as resistance change by use of resistance elements can be accurately measured with this instrument. The measuring circuit is a Wheatstone Bridge, A.C. energised, and the out-of-balance e.m.f. derived from the circuit is fed to a high gain amplifier, which in turn energises the reference phase of a 2-phase servo motor. Motion is thus obtained correct in sense and magnitude, and of a speed proportional to the value of unbalance. The servo motor drives a pointer to which is directly coupled a high precision cam-corrected potentiometer, until balance is restored. The instrument is available in ranges from −200° C. to +500° C., and has a scale length of 27 in. Full-scale travel is effected in one second for full-scale interval of 50° C. or greater. Shorter temperature ranges spread over the full scale can be accommodated, but involve a small increase of travel period.

An automatic cancelling push button switch has been specifically designed for multi-way temperature applications, and is particularly suited for use with the high speed temperature indicator. The automatic cancelling push button feature facilitates instantaneous selection of any desired point. Delays in gathering and correlating process control temperature data are thus reduced to a minimum.

Setting up a Subsidiary in Canada

The Board of Trade has produced a 14-page pamphlet for the guidance of those firms who may be considering setting up a subsidiary organisation in Canada. It makes no claim to be more than an introduction to the subject, but it touches on most of the more important factors which have to be taken into account, such as, for example, application to the Bank of England and Treasury ; the difference between Dominion and Provincial registration ; solicitors' fees and fees for incorporation ; selection of a name ; and Federal, Provincial and other taxation. It includes an appendix listing useful contacts in the Provinces of Canada.

The pamphlet will be sent free on request. Applications should be addressed to the Board of Trade, Commercial Relations and Exports Department, Room 4170, Horse Guards Avenue, London, S.W.1. (Telephone : TRAfalgar 8855, Ext. 2625).

The British Internal Combustion Engine Research Association

At the recent Annual General Meeting of BICERA, the Rt. Hon. the Viscount Falmouth, was re-elected President. Sir Harold Cox, F.R.S. ; Dr. S. F. Dorey, C.B.E., F.R.S. ; Chief Engineer Surveyor, Lloyd's Register of Shipping ; Major-General H. R. B. Foote, V.C., C.B., D.S.O., Director-General, Fighting Vehicles Division, Ministry of Supply ; and Vice-Admiral (E) F. T. Mason, C.B., Engineer-in-Chief of the Fleet, were re-elected Vice-Presidents. Mr. G. W. Bone, Mr. J. Calderwood, Dr. A. R. Morcom and Mr. A. V. Wilkin were elected to the Council, which also includes Mr. H. D. Carter, Mr. C. G. Tangye, and Mr. G. A. McMillan.